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THE MOON. II.

WM. W. PAYNE.

In the September number of this journal, page 18, reference is made to the advancement of Astronomy during the time of Aristarchus, Hipparchus and Ptolemy. So much interest attaches to the period in which these men lived and worked, that more ought to be said about them before we go on with the later studies of the Moon, although all that we shall notice is matter of history within the reach doubtless of many of our readers.

Aristarchus* of Samos (320–250 B. C.) was a member of the Alexandrian school of Greek philosphy in which ancient astronomy made great advancement. Progress at this time was largely due to the use of superior instruments and to systematic work in observation. He was the first astronomer of marked ability in this school, and his recognition, as such, chiefly grew out of the fact that he first proposed the heliocentric theory (Sun at the center) of the solar system, similar to that taught by Copernicus later, although the new theory was not accepted by astronomers at this time. He also determined the distances of the Sun and Moon from the Earth by very ingenious methods. He found the distance of the Moon to be fifty six times that of the radius of the Earth, and that of the Sun *nineteen* times as great as that of the Moon from the Earth. By his measures the diameter of the Moon was 2°, and the Sun's parallax was 3 minutes of arc in value. We now know that the Moon's distance from us is about 60 times the Earth's radius, that the distance of the Sun is about 390 times that of the Moon, that the Sun's parallax is 8.8 seconds of arc nearly, and that the angular diameter of the Moon is 31′. In first reading we wonder at these great errors of value in almost every instance given above, and ask ourselves if such work was the best that astronomers of this period could do. These instances fairly indicate the degree of precision which astronomy had reached in obtaining fundamental data for the science in these times. It can now be said that Aristarchus, in obtaining the above erroneous results, was right in principle and

* Neison's, *The Moon*, page 82.

method. He was correct in principle and even ingenious in method. He failed to get better results because his appliances were rough and unequal to the delicacy of measure required. Considering the nature of his instruments the values obtained by his observations were the best and the most delicate that could be certainly expected. Although his solar parallax was 20 times as large as it should be, no one could then improve it, and it was adopted by Ptolemy and thought to be the correct value for twenty centuries afterwards.

Erastosthenes (276–196 B. C.) took up the work and tried to obtain the size of the Earth by observing the difference of zenith distance of the Sun at two different places. He made the radius of the Earth 5000 miles, the distance of the Moon 98,000 miles and the distance of the Sun 100,000,000 of miles.

Hipparchus (190–120 B. C.), however, was the ablest observational astronomer of this period. He discovered the elliptical nature of the Moon's orbit, found its inclination to the Earth's path to be 5°, determined the period of the revolution of the Moon's nodes to be 18⅔ years, by parallax found the Moon's distance to be 59 radii of the Earth and the diameter of the Moon as 31′, an exact determination.

For a period of a hundred years the work just mentioned is unexpectedly far in advance of that described earlier in this article, especially when we remember that it was all done with naked-eye instruments. When the study of instruments for observation is taken up later, those in use in these early times will be illustrated and particularly described.

Ptolemy (100–170 A. D.) carried the ancient astronomy of the solar system to its highest perfection in a theory usually now called from his own name, the Ptolemaic system. It was worked out in 140 A. D., at Alexandria and was published in Arabic, under the title, *Almagest*, and was for fourteen centuries a work of supreme authority in Astronomy. In this theory the Moon is represented as revolving around the Earth in a circle, while the latter body is not placed at the center of the circle. The explanation of the motions of the planets and the Sun as determined by this theory will be found in almost any good, modern text-book on Astronomy and need not be repeated here. It need only be added, that scarcely a single thing which this theory claims, is true as we now know, yet cumbersome in detail as it was it completely represented the best observation for a period of 300 years. Who then could successfully dispute the theory of Ptolemy for the long interval following, seeing that the necessary data for such

reasoning was wholly wanting, if we except a few observations which Ptolemy was apparently unwilling to set against all others with the weight and real value that belonged to them?

This brief review gives the reader some idea of the progress in lunar and some kindred studies to the time of the invention of the telescope.

We present herewith a picture of the full Moon because the opportunity for taking it, just exactly at the phase wanted came at the date upon the plate. The Moon was then within a few minutes of the full and its declination was 28° 17′, making its zenith distance in this latitude nearly as small as possible, hence its libration in latitude was favorable for viewing surface beyond the south pole. It was also very near the meridian. When we take another picture with libration large in the opposite direction we will have a pair of them that may be used with good effect for stereoscopic pictures. This picture will also be referred to in later descriptions of surface markings visible at this phase and others which may nearly precede or follow it.

OPTICAL GLASS.

With Special Reference to Telescope Objectives.

J. A. BRASHEAR.

Testing for Striæ.

As stated in our last article, warranted discs of optical glass are always polished on the two faces for the purpose of studying the character of the material, as well as the annealing. Plates of best quality are polished on the edges only.

Fortunately we have quite simple methods at our command by which we are able to determine whether it is safe to make an objective of the glass in question, for it would be a rather costly matter if we found, after working for many weeks upon an objective, that it had defects in it of such a serious nature that they would render it worthless for astronomical or other purposes of research.

The unaided eye can see stones, bubbles or seeds in the glass, but these things, which disturb the equanimity of the novice, are of the smallest concern to the practical optician. Many of the finest objectives have a large number of bubbles in them, but generally speaking all the harm they do is to stop a little light. The

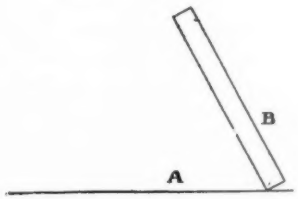
Washington 26-inch has perhaps a hundred bubbles in the body of the glass, but the 23-inch at Princeton is remarkably free from them. Bubbles are a little unpleasant to the eye, but the practical man, who knows how little harm they do, is glad to pass them by as an insignificant factor if the glass is otherwise all right.

There is no doubt that unequal density of the different parts of a disc of optical glass is the most serious fault it can have, but our glass makers of to-day are very successful in avoiding this difficulty in a large degree, and this is fortunate for there is no satisfactory way to determine this quality until the objective is ground, polished and set up for a preliminary test. But aside from this it is necessary to determine whether the glass is otherwise homogeneous in its nature, *i. e.*, free from "chords" or striæ as the glass makers call what appears as glass or other vitreous substance in the form of light or heavy threads throughout the glass, but slightly different in density or other characteristics from the material of the discs else it could not be detected and would do no harm.

There are two or three methods to detect striæ or chords in glass plates or discs. Perhaps the best method is not readily available to many of our readers, but as it is so excellent and is also valuable for another important investigation I will describe it briefly.

The first requisite is a concave silvered mirror such as is used for a reflecting telescope. The second, a lamp with a cylindrical screen over it with a hole drilled in it about two tenths of an inch in diameter at a place where the maximum light of the lamp flame will pass through it. The disc or plate must be fairly well polished, no attention being paid to scratches, although a novice will at first find some difficulty in deciding between a scratch and some kinds of striæ. The mirror is placed in a vertical position at a convenient height, *i. e.*, so that the center of mirror will be at the same height as the opening in the lamp screen, the lamp being placed on a stand or table. The plate or disc of glass is set upon edge close to the mirror, indeed may lie against it if desired. The lamp is now moved to the approximate center of curvature of the mirror, which will be modified somewhat by the shape of the glass to be tested, but this is of no importance, as all that is necessary is to move the lamp in either direction until the apex of the reflected beam of light comes to a place near the same plane as the lamp, but even this may be varied without detriment to the test, the idea being to concentrate the returning beam upon

the pupil of the eye after it has been reflected from the mirror through the glass to be tested. The lamp must be moved a little to one side of the optical axis of the mirror so that the returning beam will be far enough removed from it to allow the eye to intercept it.



This method of testing brings out striæ, chords or any other imperfections so perfectly that dirt spots, scratches, stains, etc. must be eliminated from chords and striæ. One drawback upon this method is that it is difficult to locate the position of the stria if such be present, with respect to one or other of the surfaces, a matter of great importance, as, when the stria is near one surface the rough grinding may be done so as to cut out the imperfections entirely. The usual method for testing for striæ is as follows:

The same lamp and screen may be used, but the writer finds a candle a first-rate substitute. In this method the candle may be set on a bracket or other support and should be from ten to fifteen feet away from the glass to be tested, according to the focus of the lens to be used for condensing the light. In my own practice I prefer to hold the condensing lens in my hand, so that the conjugate focus of the lens, on the side you are using it to condense the light should not be greater than six or eight inches, otherwise it becomes very tiresome to hold it. A second person can hold and shift the lens, but it is then a very difficult matter for the observer to follow the transmitted beam of light as it traverses the various parts of the disc. Indeed, on first trial, it will be found quite a task to keep the eye in the path of light from the lens, under the best conditions, particularly so when the glass to be tested has one of the surfaces convex or concave.

The disc or plate to be examined may be held vertical in any convenient way, or the lens may be held stationary and the plate moved in front of it if the latter is of small dimensions.

The accompanying sketch shows at a glance the arrangement. *a* is the candle, *b* condensing lens, *c* plate to be tested, *d* the eye placed where it will receive the full beam of light. The room for this work should of course be dark.

It is usual to place the lens between the source of light and the plate or disc of glass, but the writer has just as good success by allowing the light to pass through the plate first, and this method offers advantages in testing large discs, because the lens can be moved over any part of the surface, and if stria is detected, its parallax may be found in a very simple manner, as follows:

Having located the stria, a mark is made in line with it on either of the surfaces, using a small piece of bees-wax or paraffine in making the mark. Condensing the beam of light upon it, the eye is moved to and fro to see if the line of stria shifts with relation to the surface mark. If it does not shift we may conclude that the stria is very close to the surface having the mark upon it. If it does shift then it is best to place a similar mark on the opposite side and observe again, as the stria may be near this side. If, however, the stria shifts in relation to both marks on the glass, we must conclude that it is in the body of the material and a careful study will determine if it is nearer one side than the other. Striæ very frequently cross diagonally through the plate, and then there is but little hope of saving it.

One used to studying glass can readily detect striæ through the polished *edges* of a plate, in which case it may readily be determined whether they are near enough to the surface to be eliminated or not. Striæ and other defects may readily be photographed but eye observations are the most satisfactory.

It is a question with opticians how much striæ may remain in a glass and be harmless. Perhaps there are not many large discs that are perfectly free from small lines of striæ, but the writer will not use a piece of glass that has any striæ that can be de-

tected by ordinary means, and he would recommend to the amateur never to purchase anything but first class plates if he wishes to obtain the highest results. As a proof of the satisfaction in purchasing first quality glass I would say that out of about 500 pieces crown and flint made for me by Mantois of Paris, but one piece 3 inches in diameter has been found with a single stria in it. I have just finished testing the 23-inch discs exhibited at the World's Fair by the Jena manufacturers, and find the crown absolutely free from striæ. A small "bunch" of striæ was located near the edge of the flint; but it was found to be on the surface that will have a convex curve given to it, and not a particle will be left in the disc when finished.

Such discs are of course warranted by the makers, yet it may be seen how important it is that they be critically "diagnosed" before work is commenced upon them.

Perhaps I should give a few directions as to polishing *plate*s for preliminary tests.

Grind on plate glass, commencing with rather coarse emery, say No. 90, then with No. 140, then one or two grades of washed emery, prolonging the grinding with the finer emeries until a clean surface is obtained. The crown may be ground on the flint if desired. A felt or cloth surface may be used for the polishing tool, using rouge as a polishing material. A friend of the writer uses the heavy blue cloth made for army clothing and says it answers well. I prefer a pitch polisher for my own use. If cloth is used it is cemented to a flat iron tool using heated coal tar pitch as a cement, and pressing the cloth to a surface with the glass plate which has been previously wetted. A good bright polish is all the better for testing the glass, both for striæ and by polarized light, but the flatness of the surface is of no moment whatever.

It may be of use to our readers to know that rouge and prepared emeries may be purchased of the best quality and at reasonable prices from Mr. Geo. Zucker, 616 West 39th Street, New York.

In our next article we will give methods of testing glass for the character of its annealing.

SHOOTING STARS.

How to Observe Them and What they Teach Us.

W. F. DENNING.

VII.—The Shower of Leonids.

Like the Perseids the Leonids date their observed returns from a remote period several displays having been noticed and historically recorded in the tenth century. Professor H. A. Newton gave a valuable summary of early displays of Leonids, in the *American Journal of Science* for May 1864. The introductory shower appears to have been witnessed in A. D. 902 (nearly 1000 years ago) when meteors are stated to have been too numerous to count and to have fallen as thick as rain. A comparison of the different dates showed that the group developed its maximum intensity at intervals of little more that 33 years, so that approximately there were three brilliant reappearances in 100 years and that, virtually, the same years of each century brought the shower back. Thus the phenomenon was seen in striking grandeur in 902, 1002, 1202 and 1602 and it will recur in 1902 though we may undoubtedly expect the richest displays in 1900 and 1901. In modern times the years 1799, 1833 and 1866 have furnished the most brilliant returns, and the close of the present century and opening of the next will be sure to reward observers with a spectacle which, in its full significance, may be said to come but once in a generation.

The identity of orbit of Tempel's comet of 1866 and these November meteors formed an intensely interesting item in the progress of this branch of astronomy. The comet was computed to have a periodic time of 33.18 years and it is due at perihelion in 1899. There is little doubt that this comet is the same as one observed in China in 1133 and 1366; it is apparently composed of a vast and distended stream of stones with which the Earth comes into collision at the middle of November in several following years near the time of the comet's of perihelion. Thus there were very abundant showers of meteors in 1864, '65, '67, '68 and '69 as well as in 1866, and they prove that the stony fragments forming the comet's material are distributed thickly along a considerable portion of the orbit. During the ensuing few years observers will probably note an increasing activity in the visible returns of this system, and we have evidence of this in Professor

Barnard's statement (POPULAR ASTRONOMY, Vol. 1, p. 192) relating to the shower of 1893, that the meteors were more abundant than he had ever seen them before.

The radiant point of the stream is placed amid the well known stars forming the sickle of Leo so:—

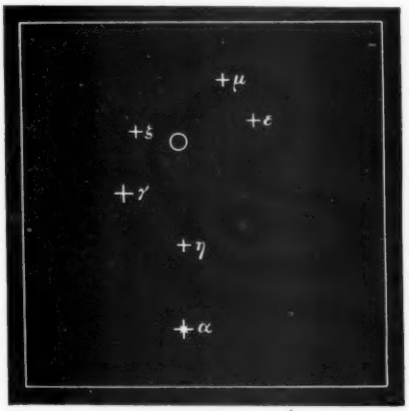


FIGURE 8. POSITION OF THE RADIANT IN THE SICKLE OF LEO.

From observations at Bristol the exact position of the radiant has been determined at

$$150°.0 + 22°.9.$$

From a mean of 40 good observations by various astronomers in different years the place is

$$148°.9 + 23°.0$$

The radiant is not well clear of the horizon until nearly midnight, so the display is always seen to the best effect in the morning hours.

The system really forms a complete ellipse, for a few meteors belonging to it are recognized every year at the appointed time. No doubt the particles are but sparsely scattered in certain parts far from the parent comet, but the continuity of the stream is manifested by its regular recurrence every November. In 1879 a marked shower of Leonids was observed at Bristol and other places, and in 1880 E. F. Sawyer of Cambridgeport, Mass., redetected it. In the latter year the comet was nearing its aphelion, so the meteors seen must have been placed at the opposite part of the orbit.

Careful observation of the Leonids, especially when the display is not so bright as to engage the whole attention, has proved that a very large number of contemporary showers are in action. The radiant points of many of these are now tolerably well ascertained. We give below a summary of 68 of them; the positions depend mainly upon observations at Bristol between 1876 and 1888:—

Radiants visible with the Leonids November 10–15.

5 + 52	62 + 34	110 + 25	166 + 3
8 + 36	63 + 21	120 + 15	166 + 31
19 + 30	64 + 11	121 ± 0	170 + 47
27 + 71	70 + 66	124 + 55	177 + 10
29 + 37	72 + 4	125 + 40	184 + 29
30 + 16	73 + 42	132 + 21	190 + 21
32 + 51	75 + 15	133 + 31	191 + 58
40 + 10	77 + 32	133 + 48	194 + 67
43 + 6	79 + 51	133 + 70	200 + 57
45 + 60	80 + 24	136 + 8	213 + 35
46 + 21	86 + 75	141 + 27	213 + 75
48 + 43	87 + 20	143 + 50	238 + 49
50 + 30	97 + 27	143 + 69	262 + 64
53 + 71	99 + 44	146 + 8	270 + 70
57 + 18	102 + 73	154 + 41	284 + 43
60 + 28	103 + 48	157 + 49	315 + 60
60 + 49	107 + 11	157 + 74	338 + 59

There are many slow meteors diverging from Perseus and Taurus at this epoch and the region surrounding Leo contains several radiants of bright, streak-leaving meteors. The writer believes the richest of the minor showers lies at the point 154° + 41° a little S. of μ Ursæ Majoris and just outside the N. boundary of Leo Minor. When the Leonids are weakly represented this shower of Ursids takes the foremost place, and some of its meteors are liable to be mistaken for Leonids, as they are very similar in appearance and the radiant is less than 20° distant from that in Leo. The shower near μ Ursæ appears to have first been discovered by F. W. Russell of Natick, Mass., for he gives a radiant at 156° 30′ + 40° 40′ from 11 meteors recorded on November 10, 1861, and the observation is quoted in Professor Eastman's valuable "*Progress of Meteoric Astronomy in America*," p. 328.

There is also a shower at 141° + 27° (close to κ Leonis) which is occasionally well defined, as in 1892, at the period of the Leonids and liable to be confused with the major shower.

Heis found from his observations in November, 1839, to 1847 that of 407 meteors registered, 171 proceeded from Perseus near the star η, and only 83 from Leo. Schmidt in 1851 remarked

that Perseus appeared to furnish the greater number of meteors not only in August but throughout the year. In order to test Heis's result the writer examined the paths of 691 meteors observed at Bristol in November 1876-79 and found that there were 50 Perseids and 50 Leonids while there were no less than 99 Taurids. The activity of the autumnal Perseids in former years appears therefore to have been succeeded by an abundance of Taurids and the point is recommended to the attention of future observers.

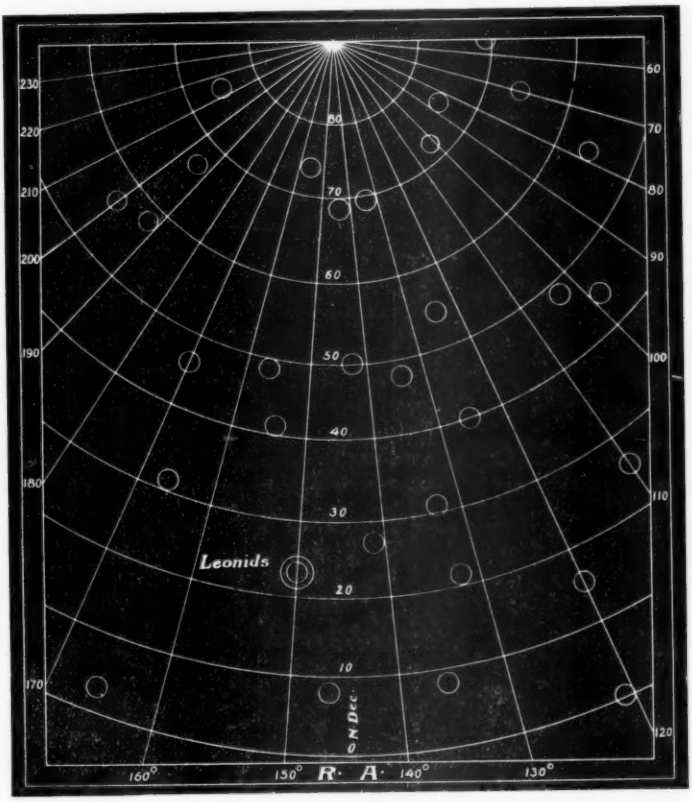


FIGURE 9. RADIANTS VISIBLE IN THE SAME GENERAL REGION AS LEO, NOVEMBER 19 TO 15.

The visible duration of the Leonid shower is much shorter than that of the Perseids and it is apparently confined to the 9 nights

from November 9 to 17. It is not yet definitely proved whether the radiant shows a displacement similarly to that of the August shower, but this is highly probable. There are generally very few Leonids to be seen except on one or two nights near the date of maximum, and it has been difficult to determine the place of the radiant at the advent and extinction of the shower. From what the writer has seen he regards the radiant as a shifting one and believes that it is possible to ascertain the rate and direction of its motion by very careful and long sustained observation.

It is a curious circumstance that in November, 1898 (or 1899), two fine meteoric displays may come nearly together. There ought to be a plentiful return of the Leonids on the morning of November 15 while the Andromedes should reappear on the 23d. or only 8 days afterwards. Thirteen years elapsed between the great Andromedec showers of 1872 and 1885, and a similar interval brings us to 1898. If the two systems fulfil expectation meteoric observers will find their hands full of attractive work, and no doubt the general public will take advantage of the opportunity to witness two of the most attractive spectacles which it is possible for the heavens to afford. A meteoric display of the finest character is certainly a most imposing and striking event and presents a peculiarity of aspect which must live long in the memory of those who witness it. Other celestial occurrences have, it is true, their remarkable features, for a large comet, a total solar eclipse and a brilliant display of Aurora Borealis are each magnificent in their way—but a meteoric storm is perhaps the most impressive and animated of all nature's wonders, for the whole firmament becomes, as it were, alive with shooting stars of all magnitudes and gives the idea of a celestial bombardment well calculated to strike terror into the minds of people not acquainted with its real meaning and harmless character.

THE FIXED STARS.

W. H. S. MONCK.

II.

Every one notices the fact that some stars are brighter than others, and stars have from early times been roughly classed as of the first, second, third magnitudes, etc., accordingly. These classifications were not based on any fixed principle, and different astronomers classed certain stars differently. The defects of such

a system were obvious and among other things it often prevented the variations in the light of a star from being recognized, or led to the supposition that there were variations where there were none. It was not until the present century that star-magnitudes were classed upon any scientific basis. It was then noticed that our power of detecting the difference between two lights depended not on the difference between the quantities of light but on the ratio between them (a principle known as Techner's law), and that on an average the stars classed as of one magnitude by astronomers gave about 2½ times as much light as those of the magnitude next below. For convenience of computation the ratio equivalent to one magnitude was fixed at the number whose logarithm is 0.4 and whose value to three decimal places is 2.512. The adoption of this scale enabled astronomers to express star-magnitudes much more accurately than before; for example, instead of describing a star as intermediate between the third and fourth magnitudes, we were able to describe it as of magnitude 3.45 or 3.87 as the case might be, provided that we could measure the quantity of light with the requisite degree of accuracy. Photometers for comparing the light of stars with each other were next invented. Those generally in use depend on two different principles. With photometers of the first kind we equalize the light of two stars by means of an instrument which reduces the light of the brighter in a known proportion. We then know the ratio of the light of the two stars or the difference in their magnitudes on the photometric scale, and if we know the magnitude of the one we know the magnitude of the other also. In the second method the light of both stars is extinguished by being passed through a wedge of neutral-tinted glass and the ratio of the lights is inferred from the respective thickness of the glass necessary to extinguish them. Both methods enable us to estimate the difference in magnitude of any given pair of stars and as a rule there seems to be a fair agreement between the results attained by them. We have only then to assume a magnitude for our standard star and we can assign magnitudes to all whose light is capable of being measured by the photometer. The pole star is naturally selected as the standard being always at an altitude (in these latitudes) capable of easy observation. In the well known *Harvard Photometry* its magnitude is assumed to be 2.15 and the magnitudes of all other stars in the catalogue are computed on that basis. The list of magnitudes thus computed is easily converted into a table of the relative quantities of light. Thus if we take Q as the

quantity of light given by a star one magnitude brighter than the first, the quantity of light given by a star of the nth magnitude is $Q^{-0.4n}$. The reader may at first be startled at hearing of stars above the first magnitude but every one knows that some stars of the first magnitude are brighter than others. Taking the magnitude of the pole star at 2.15 the star whose magnitude most closely approaches the first is α Aquilæ or Altair. Arcturus, according to the *Harvard Photometry*, is nearly one magnitude brighter than this or very nearly of magnitude 0, while Sirius is more than two magnitudes brighter, which is indicated by giving its magnitude a negative sign, — 1.43. Of course on this scale the lower the magnitude the brighter is the star, and as a star of the first magnitude is brighter than one of the second, a star of magnitude 0 is brighter than a first magnitude star, and a star with a negative magnitude is brighter than one of magnitude 0. The *Harvard Photometry* contains the magnitudes of over 4,000 stars determined in this manner, and there are other valuable collections. Errors will of course creep into any such system of measures but there is reason to think that they are small. Careful observers, moreover, though dependent on the eye only have succeeded in estimating the magnitudes of stars to tenths of a magnitude with an accuracy that photometric measures of the same stars have fully attested.

As light decreases in proportion to the inverse square of the distance the natural assumption to make in the first place was that the differences in the light of stars was mainly, if not solely, due to their distances. Thus a star of the 10th magnitude only gives $\frac{1}{10000}$ of the light of Arcturus (taken as of magnitude 0). Hence it might be assumed to be 100 times as distant, since, if removed to that distance, the light of Arcturus would be diminished in this proportion. But as soon as the spectroscope and the photographic lens were brought into use it was found that any rough conclusions of this kind needed considerable modification. Photography indeed afforded a new kind of photometry—a brighter star producing *ceteris paribus* a larger disc on the photographic plate and *vice versa*. But red stars were found to give smaller discs, and brilliant white or bluish stars larger discs, than were expected. A star which looked fainter to the eye often proved more effective in photography than a brighter one. Feebler in optical rays it was more powerful in photographic rays. The spectroscope gave the same result. The light of different stars differed in kind. The relative intensity of the light at different parts of the spectrum was different and so were the lines

which characterized the substances in the stellar atmosphere. Different stars gave different kinds of light and the analogy of terrestrial substances indicated a cause for this difference. When we gradually heat a body it first becomes red hot—it gives red light only. But gradually as the heating proceeds the light becomes whiter and is found on analysis to extend further towards the violet end of the spectrum. Finally it passes beyond the violet end giving in addition to the visible rays others which are invisible to the eye but nevertheless produce well-marked effects on the photographic plate and indeed may be rendered visible by passing the light through a fluorescent substance. The light as the heating proceeds assumes a greenish or bluish tint and the point of maximum intensity on the spectrum moves steadily from the red towards the violet end. It is needless to say that as the heating goes on the quantity of light given out by the body is largely increased. These results are generally applicable to the stars though with some qualifications; for the color of a star undoubtedly often depends to a considerable extent on its atmosphere—an absorptive medium interposed between us and the real source of light. Still it is impossible to doubt that different stars differ widely in temperature and luminosity and that the light which we receive from a star depends not merely on its mass and its distance but also on its temperature or on the intrinsic brilliancy of its surface.

When these results were reached it was natural to infer that there were dark stars in existence or at least stars so feebly luminous as to baffle our best optical instruments though comparatively near us. It was found even before Herschel's discovery of the physical connection between certain double stars that the magnitude of certain stars varied in a manner strongly suggestive of a periodical eclipse. Of these Algol is the best known but the number of variable stars of this type has been considerably increased by recent research. From the motions of Sirius it was inferred that the brilliant star was being attracted by some neighboring object which telescopes failed to detect. More powerful telescopes were used and the disturbing star was discovered: but though from its action on Sirius it is computed to be perhaps half as large as its brilliant companion it does not give $\frac{1}{10000}$ part of the light. A similar result was arrived at in the case of Procyon where even the great Lick telescope has failed to detect the smaller star. The spectroscope has added to this list as will be seen hereafter. Almost simultaneously it was conjectured that some of the outer planets gave a little light of their own be-

sides reflecting the sun-light. We have, however, unmistakeable evidence of dark bodies within the solar system. The inference (subsequently confirmed by other considerations) seemed to be that dark bodies exist outside of the solar system also—that in short stars exist in every possible degree of illumination from one considerably exceeding that of the Sun down to absolute blackness. And the number of black stars (or black bodies in space) may be far greater than we imagine because it is only by some accident that we can detect their existence at all.

The distribution of stars in the sky is evidently not uniform. But when we are dealing with large classes of stars distributed impartially over the sky an approach to uniformity might reasonably be expected. It is therefore worth while to consider what the effect of uniform distribution would be as regards the number and light of the stars of each magnitude. Supposing that no light is lost in transmission we may assume for instance that all the stars up to and including the fifth magnitude are included in a sphere having the Earth as its center and the radius r. All the stars up to the sixth magnitude will then be comprised in another sphere having the same center and the radius $1.585\,r$ — 1.585 being the square root of 2.512 the multiplier which corresponds to a magnitude and the intensity of the light varying inversely as the square of the distance. And if the number of stars comprised in the first sphere be n the number comprised in the second sphere will be $(1.585)^3 n$ or $3.984n$. Of these stars $2.984n$ will be stars between the fifth and sixth magnitudes the total number up to and including the fifth magnitude being n as already stated. Using for brevity 4 instead of 3.984 the stars of any magnitude will thus be three times as numerous as all the brighter stars. Applying the same rule to the stars between the fourth and fifth magnitudes their number will evidently be $\frac{3}{4}n$ and those brighter than the fourth magnitude $\frac{1}{4}n$. The stars of any magnitude will thus be four times as numerous as those of the magnitude next below. This reasoning, it will be seen, is perfectly general. Let us now compare the total light of the stars of two successive magnitudes. The average light of the brighter stars is 2.512 times that of the fainter but the number of the latter is four times as great, and their total light is 1.585 times greater. The total light increases at each magnitude by the number whose logarithm is 0.2. Thus the stars of the tenth magnitude should give collectively ten times as much light as those of the fifth magnitude, the stars of the fifteenth magnitude 100 times as much light and so on. And if this uniform distribu-

tion of the light extended to infinity the total amount of light received from the sky would be infinite. But nothing is more evident than that the total light of the sky is of very limited amount. The full Moon bursting through a dense cloud when the rest of the sky is overcast gives more light than we receive from the whole sky on a clear moonless night. What is the explanation of such facts as these? Is the universe finite? Or is there some medium in space which absorbs light and causes it (especially at great distances) to diminish more rapidly than in the ratio of the inverse square of the distance? Or lastly is the region of luminous stars limited, the bodies at greater distances being usually dark? These are among the problems which the astronomy of the future has to solve.

So far as I have compared photometric measures of stars I think the theoretical proportion of 4 to 1 for the numbers of stars of two successive magnitudes is rarely if ever realized. If all stars are of equal intrinsic brightness and light diminishes as the inverse square of the distance, a thinning out commences at (comparatively speaking) no great distance from the Earth or the Sun. But though the proportion seldom if ever reaches 4 to 1 it seems always to exceed 2.512 to 1, and as long as it does so the total light of the stars of each successive magnitude will continue to increase. The limited amount of light which we receive from the entire sky shows that this process cannot go on very long, but where it stops is at present a subject of conjecture only. The stars of the 100th magnitude may collectively give as much light as those of the fifth but I think if the process was carried on as far as the stars of the 1000th magnitude the total light of the sky could not fail to be much greater than it is. That there are dark bodies both within and without the limits of the solar system which intercept some of the light of distant objects must I think be conceded, but this will not account for the observed thinning out of the stars unless we suppose them to be more numerous than is usually supposed. A given quantity of matter will intercept the greatest quantity of light when it is most subdivided. If meteors exist in space to anything like the extent which the Meteoritic Hypothesis supposes, a good deal of the light coming from distant objects must be intercepted by them. But the ether itself may absorb light or convert it into some other form of energy. The entire problem is one of great interest but the solutions hitherto proposed are chiefly speculative. It will be desirable to bear in mind however, that we can only believe in the existence of an infinite Universe of luminous bodies on the hy-

pothesis of a very large absorption of light in the case of the more distant stars—a much larger absorption than in the case of nearer stars and which therefore is not to be explained by the stellar atmospheres or the terrestrial atmosphere but by something which intervenes between us and these stars.

Whether the distribution of stars round the Earth is approximately uniform as regards distance or not, it is undoubtedly not so as regards direction. That the stars are far denser in the Galaxy than elsewhere, and in particular parts of the Galaxy than in other parts, has been long known. And as telescopes with increasing power came to be used it was found that in many parts of the sky remote from the Galaxy there was an evident thinning out of the stars at stages where there was a thickening in most parts of the Galaxy. There are parts of the sky remote from the Galaxy where, if we examine the fainter stars with a more powerful telescope or a photograph taken with longer exposure, instead of the four-fold increase for each magnitude there is sometimes an actual decrease. It seems as if we were looking *through* the stars in that direction and that there were no others beyond them. On the other hand the four-fold ratio must at some stages be greatly exceeded in such regions of the sky as that in Cygnus where Mr. Roberts photographed 16,000 stars not one of which was as bright as the sixth magnitude. Observations like these give rise to further problems. Are we *in* the Galaxy or outside it? Do all thestars which we can detect with our present optical means belong to one great galactic system or does that system only include a certain number of them? And what is the shape of this Galaxy? The Galaxy as visible may be described as a very irregular ring whose central line forms a great circle on the celestial sphere. But is it really a ring, the Sun and Earth being somewhere in the vacant space which it encircles, or is it shaped rather like a block-wheel the solar system lying within the block and the stars being thinner in the direction parallel to its axle than at right angles to it for the simple reason that they extend to a shorter distance in the former direction than in the latter? This shape would of course account for our being able to look through the stars near the poles of the Galaxy while failing to do so in the direction of the Galactic circle. All stars would on this latter assumption form part of the same vast system, or at least if there are any stars independent of it we have hitherto failed to detect them. On the other hand if the Galaxy is shaped like a ring—a spoke-wheel instead of a block-wheel though of course the spokes are imaginary—we are outside

the galactic system and so are our nearer neighbors, the nearest part of the ring being situated at a great distance from us. Of course both the block-wheel and the spoke-wheel are very rough illustrations but they may serve to distinguish the two systems, one of which makes the Earth and all visible stars part of the galactic system while the other excludes us and our nearer neighbors from it. We are not probably in a position to decide positively between these two theories at present but observations on the proper motions of the stars and to a certain extent observations on their spectra may assist us in making a probable conjecture. But it will be necessary to describe the spectra and the proper motions of the stars before this question can be discussed with advantage. The shape of the Galaxy cannot be determined till we know what stars are to be included in the galactic system, and even then it will be difficult to determine how far its apparent shape is the result of perspective or projection on the celestial sphere.

Attempts have been made to compare the light of some of the brighter stars with that of the Sun but with very unsatisfactory results. The difference is too great and we cannot even observe them simultaneously. The method adopted was comparison with the Moon but various estimates make the light of the Sun greater than that of the Moon in proportions varying from 300,000 to 800,000 to 1. The proportion of incident sunlight which the Moon reflects is also doubtful and the full Moon is too bright for accurate comparison with the light of a star. A comparison of the light of the fixed stars with that of the planets promises better results but there is still an uncertain element—the *albedo* of the planet as it is called, or the proportion of the incident sunlight which is irregularly reflected from its surface. If the entire visible hemisphere were covered at the distance of the planet by a substance which irregularly reflected the whole of the light that fell on it we should receive from this hemisphere as much light as we receive directly from the Sun. We can compute the proportion which the planet's disc (or rather the illuminated portion of it) bears to the entire hemisphere in question and thus compare the planet's light with that of the Sun on the assumption that the whole of the incident light is irregularly reflected from the illuminated portion of the planet; and comparing the light of the planet with that of a star we can obtain the proportion between the light of the Sun and that of a star on this hypothesis. But the planet does not reflect the whole of the incident light and there is a question as to whether some of the planets do not give

original as well as reflected light. Our results are consequently uncertain. I may mention, however, that on the lowest estimate of the light of Sirius that has hitherto been made the light of the Sun exceeds it in the proportion of 20,000,000,000 to 1. But the distance of Sirius, as will be explained hereafter, is supposed to be about 500,000 times as great as that of the Sun, and at this distance the Sun's light would be diminished in the proportion of 250,000,000,000 to 1. Sirius thus gives on this computation 12½ times as much light as the Sun. Other computations however make it more than 60 times as bright.

CONSTELLATION STUDY.

WINSLOW UPTON.

V.

Continuing the description of the individual constellations begun in the last article of this series, we will take up those in the first division which are south of north declination 50°. We have already considered Cassiopeia and Camelopardalis, the two circumpolar groups of this division. The three zodiacal constellations, Pisces, Aries and Taurus, will first be described, and then those which lie north and south of them.

Pisces.—This interesting group is composed almost entirely of faint stars, and cannot be traced except on clear, moonless nights. It can be found as follows: The four stars marking the equinoctial colure were α Ursæ Minoris, β Cassiopeiæ, α Andromedæ and γ Pegasi. The line connecting the last two forms the eastern side of the very conspicuous quadrilateral known as the square of Pegasus. Directly south of the Square is a cluster of small stars encircling an area which resembles a polygon of five or six sides. This marks the western fish. Directly east of the Square is a second cluster of faint stars which marks the eastern fish. Two winding lines of stars, running the one eastward from the first fish and the other southward from the second fish, meet at the fourth magnitude star α Piscium, the brightest of the group. The classic figures are drawn with the fishes pointing westward and northward respectively, and with their tails connected by a band.

Aries. The characteristic figure of this group is an elongated triangle which marks the head of the Ram. A line drawn from

the Pleiades to γ Pegasi is nearly bisected by the group. A small triangle of rather faint stars five degrees southwest of the Pleiades may also be traced in the eastern part of the area occupied by this constellation, and marking the position of the tail of the animal.

Taurus. The characteristic figures of this constellation are the Pleiades and the Hyades. The former are in the shoulder and the latter in the head of the Bull, only the shoulder and head with the fore legs and horns being represented in the figure. Six stars can be readily distinguished in the Pleiades, and several more have been seen on favorable occasions. The Hyades or V-shaped group, whose vertex is toward the west, contains the bright red star α Tauri or Aldebaran. The middle star in the southern side of the V is a naked-eye double, the components being about 6′ apart. Two prominent stars 5° apart, mark the tips of the horns which may be found by drawing a line from α Tauri northeastward to the twin stars of Gemini, Castor and Pollux. About one-third of the way from α Tauri, this line crosses the line at the extremities of which are the two stars marking the tips of the horns. The northern one, β, is the brighter and is the second in brightness in the whole constellation.

North of the three zodiacal constellations just named lie the constellations Andromeda, Triangulum, Perseus and Auriga, given in the order west to east.

Andromeda. The characteristic figure of this group is three bright stars nearly in line, about 15° apart. The westernmost is lettered α, and has been mentioned already as in the line marking the equinoctial colure and also the northeastern corner of the Square of Pegasus. The line runs northeast, approximately towards the brilliant star Capella in Auriga, and the stars are lettered in order, α, β, and γ. Half way between α and β, a little south of the line is δ, somewhat fainter than the others, and the line may be prolonged to a bright star beyond γ, which is in Perseus and called α Persei. This line is near the southern boundary of the area, and there are a number of fainter stars north of it, which should be associated with the figure. Several of these are near γ, and from β runs a line of faint stars at right angles with the α, β, γ line, which leads to the nebula of Andromeda, just visible to the naked eye. In the figure of the "chained lady" this line of stars is the girdle to which the chain is fastened, and the figure is drawn with the head at α and left foot at γ.

Triangulum. This group, as its name implies, is a triangle of stars which may readily be found as it is half way between the

triangle marking the constellation Aries and the star γ Andromedæ.

Perseus. There are two characteristic figures in this area—a curved line of bright stars, and a cluster of stars sometimes given a distinct name:—Caput Medusæ. In order to find the former, continue the line α, β, γ Andromedæ beyond γ about 20° to the bright star α Persei, the brightest of the group. This is in the curved line sought for, two stars lying northwest of it, and one southeast. Several fainter stars are near these. In order to find the head of Medusa, note a triangle formed by α Persei, γ Andromedæ, and a star of nearly equal brightness south of the former and east of the latter. This star is β Persei or Algol, the famous variable star. Close to it are three fainter stars forming with it the group. Between the northernmost star of the curved line and the constellation Cassiopeia is a magnificent cluster of stars, visible to the naked eye, and a gorgeous group in the telescope. This cluster is in the sword of Perseus, and the curved line of stars is in the body of the hero. Another method of tracing the stars, including some other stars in the southern part of the area, is represented on the chart printed in this number of POPULAR ASTRONOMY.

Auriga. This group, east of Perseus, contains the brilliant star α Aurigæ or Capella. From it may be traced the other stars of the constellation;—a third and two fourth magnitude stars south of it, a second magnitude star β east of it, a third magnitude star south of β and two stars, of the third and second magnitude respectively, at the southern boundary of the area, and with those just named forming a large polygon. The second magnitude star last named is now included in the constellation Taurus and called β Tauri. It was referred to above as marking the tip of the northern horn of the Bull. In the ancient figure it also marked the foot of the charioteer and was lettered γ Aurigæ, thus affording an example of a star which was placed in two adjacent constellations.

Immediately south of the zodiacal constellations are the constellations Cetus, Eridanus and Orion, and south of Orion are Lepus and Columba.

Cetus.—This group occupies a very large area south of Pisces and Aries, and contains ten or more bright stars scattered about but forming no special figure. Two groups may be formed, first, two bright stars α and γ, lying east of α Piscium, and which with several fainter stars mark the head of the Whale, and second a quadrilateral of bright stars in the Whale's body adjacent

to which on the west are two more bright stars. The famous variable star o Ceti, which is usually invisible to the naked eye, but every eleven months attains the brightness of a fourth magnitude star, and sometimes even of a second magnitude star, is in the neck of the figure and forms a triangle nearly equilateral with γ Ceti and α Piscium, lying south of them.

Eridanus.—This winding constellation is only in part visible in northern latitudes. It begins at the eastern part of the area called by its name, close to the brilliant star Rigel in Orion, and winds westward, following the positions of ten rather faint stars. Then the stream turns southward and southeastward, the latter portion containing nine stars of nearly equal brightness all lettered τ, with the numbers 1, 2, 3, etc., added as the right ascensions increase. The stream then turns southward and westward and is lost in the haze about the horizon, as we view it in northern latitudes. Southern observers can trace it to south declination 58° where it terminates in a bright first magnitude star, α Eridani or Achernar.

Orion.—East of Taurus and Eridanus lies this conspicuous constellation, the chief features of which are the three stars of the second magnitude 1½° apart forming the belt, and the two first magnitude stars, one red and the other white, north and south of the belt respectively. The figure may be traced further as follows: The red star, α Orionis or Betelgeuze, makes a triangle with a bright star γ, about 8° west of it, and a fainter star λ north of it. Two fainter stars are close to λ and they mark the hunter's head, the stars α and γ marking his shoulders. South of the belt are three stars close together in north and south line, the northern one quite faint. These are in the sword and the middle star, θ, is the star which is readily resolved in the telescope into the trapezium round which lies the wonderful Great Nebula. The bright star southwest of the sword, one of the most magnificent in the heavens, is β Orionis or Rigel. It marks one foot (the leg drawn up) and a star 8° east of it is in the other leg. On a specially clear evening, a curved line of fainter stars near the boundary of Taurus, west of the shoulder may be readily traced, as shown on the chart.

Lepus.—South of Orion is situated this little group. Its characteristic stars are three of the third magnitude forming a right-angled triangle. They lie south of Rigel about 10°. The line from Rigel passes near two fourth magnitude stars which mark the ears of the Hare, and four other fourth magnitude stars two

southeast, and two northeast of the triangle are also easily discerned.

Columba.—South of Lepus is this constellation, the chief stars of which are a second, a third and a fourth magnitude star forming a triangle and marking the body of the Dove.

The Celestial Equator can always be imagined drawn in the sky, without the aid of any stars which are situated near it. For it intersects the horizon at the east and west points exactly, and crosses the meridian at a height above the horizon equal to 90°, less the latitude of the place of observation. Reference to the chart shows how the constellations just described are placed with regard to it and near what stars it is drawn. It will be noticed that it passes through the southern part of Pisces, the northeastern part of Cetus, the extreme southern part of Taurus, the extreme northern part of Eridanus, and nearly centrally through Orion. The brightest star in Pisces, α Piscium, is 2°.7 north of it, and the northern star of the belt of Orion is 0°.4 south of it.

The Ecliptic does not occupy any constant position with regard to the horizon, for the diurnal motion is necessarily along the equator, the stars describing small circles whose planes are parallel with the plane of the equator, and the ecliptic makes an angle of 23° 27′ with the equator. Consequently we can best trace the ecliptic by noting the constellations through which it passes, and then we can note its several positions in the sky from month to month. The ecliptic is wholly in the zodiacal constellations, except that between Scorpio and Sagittarius, in the third division of the heavens, it crosses the area named Ophiuchus. In the first division above described it shows the path followed by the Sun between the vernal equinox and the summer solstice, and hence beginning at its intersection with the equator in Pisces it is to be traced farther and farther north until it reaches its highest northern point as it enters the area Gemini. Its exact position may be readily found from the chart. It will be noted that the two fishes are wholly north of it and that it crosses both lines of stars marking the cord connecting them. The characteristic triangle of Aries, which is 20° north of the celestial equator, lies about 6° north of the ecliptic, which passes nearly half way between the Pleiades and Hyades.

The Solstitial Colure, dividing the first and second divisions of the heavens, may be approximately traced among the constellations above described. It runs only about 2° east of the two conspicuous stars β and θ Aurigæ, and it leaves the leading stars of Orion wholly west of it, the bright red star α Orionis being less

than 3° west of it. It passes almost exactly through θ Leporis, an inconspicuous star in that group, east of the leading stars of the figure, which can be found from the guiding lines on the chart.

An explanation may be needed of the words east and west as used in astronomical descriptions. North and south are more readily understood, but even in their use, confusion may arise. North is towards the north pole along any hour circle, and south the opposite direction. Thus the direction from the north pole to the north point of the horizon is south. As we face the north, the direction south is along any of the lines radiating from the north pole in any direction. As we face the south, the direction north if we start at the celestial equator is along converging lines toward the north pole, and the direction south along these lines in the opposite direction; after crossing the equator they converge towards the south pole. The direction *east* is at right angles with the hour circles and in the opposite direction in which the stars move in their diurnal motion. If we face the north and view the circumpolar stars, the direction *east* is along the diurnal paths of the stars, (which are parallel circles smaller and smaller as we approach the pole), in the direction of clock hands or *clock-wise*, and the direction *west* the opposite direction or *counter clock-wise*. If we face the south, the direction *east* is towards the left along the celestial equator or any small circle parallel with it.

The constellations of the first division can best be studied in the autumn, when they are rising in the east. Indeed as a general rule the constellations which rise and set can be most advantageously learned soon after they have risen, and they should be watched carefully for several months that they may still be recognized in their western positions. In March, the division is in the west in the early evening. Pisces and Cetus cannot be seen to advantage if at all, but the others may be traced without difficulty. If this is done it should not be forgotten that the task is only half completed, for it is surprising how different the same groups will appear six months hence when they are in the east. This is especially true of Andromeda and Perseus. For this reason, a careful review of this division of the sky should be made in the autumn evenings.

The following table contains the approximate positions of the leading stars in each constellation.

APPROXIMATE POSITIONS OF THE LEADING STARS IN THE CONSTELLATIONS BETWEEN 0^h AND VI^h RIGHT ASCENSION, OMITTING CIRCUMPOLAR CONSTELLATIONS.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
ANDROMEDA.			
α	2.1	0 3	28 33
β	3.4	0 34	30 19
δ	2.2	1 4	35 5
γ	2.2	1 58	41 51
TRIANGULUM.			
α	3.6	1 47	29 6
β	3.1	2 4	34 31
γ	4.2	2 11	33 23
PERSEUS.			
γ	3.1	2 58	53 7
β	2.3	3 2	40 35
α	1.9	3 17	49 30
δ	3.2	3 36	47 28
ζ	3.1	3 48	31 36
ε	3.0	3 51	39 44
AURIGA.			
ι	2.7	4 50	33 0
ε	3.2	4 55	43 41
α	0.2	5 9	45 54
β	2.1	5 52	44 57
θ	2.7	5 53	37 12
PISCES.			
α	4.4	1 57	2 17
ARIES.			
γ	5.0	1 48	18 48
β	2.8	1 49	20 18
α	2.0	2 2	23 0
TAURUS.			
η (Pleiades)	3.0	3 42	23 48
λ	3.6	3 55	12 13
γ	3.9	4 14	15 23
ε	3.7	4 23	18 58
α	1.0	4 30	16 19
β	1.9	5 20	28 31
ζ	3.0	5 32	21 5
CETUS.			
ι	3.6	0 14	− 9 22
β	2.1	0 38	− 18 33
η	3.6	1 4	− 10 43
θ	3.8	1 19	− 8 42
τ	3.6	1 39	− 16 28
ζ	3.8	1 46	− 10 50
o	var.	2 14	− 3 25
γ	3.6	2 38	+ 2 49
α	2.7	2 57	+ 3 32

ERIDANUS.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
γ	3.0	3 53	− 13 47
v^1	3.3	4 14	− 34 2
β	2.9	5 3	− 5 13

ORION.

π^3	3.3	4 44	+ 6 48
β	0.3	5 10	− 8 19
η	3.5	5 19	− 2 30
γ	1.9	5 26	+ 6 15
δ	2.4	5 27	− 0 22
λ	3.7	5 30	+ 9 52
ι	3.0	5 30	− 5 58
ε	1.8	5 31	− 1 16
ζ	2.0	5 36	− 1 59
κ	2.2	5 43	− 9 42
α	0.9	5 50	+ 7 24

LEPUS.

ε	3.3	5 1	− 22 30
μ	3.3	5 8	− 16 10
β	3.0	5 24	− 20 50
α	2.7	5 28	− 17 54
γ	3.8	5 40	− 22 28
δ	4.0	5 47	− 20 52

COLUMBA.

ε	3.8	5 28	− 35 33
α	2.7	5 36	− 34 7
β	2.9	5 47	− 35 48

VARIABLE STARS. V.

J. A. PARKHURST.

Systematic observations of variable stars began with the noted Argelander, who a generation ago was director of the Observatory at Bonn, Germany. He perfected the method which bears his name and in 1844 published a catalogue of 18 stars. Schönfeld had been observing variables at Mannheim for some years, and when called to Bonn to succeed Argelander, continued the work and brought out two catalogues, the first in 1866 containing 119, the second in 1875 with 143 stars. Schönfeld prepared the ephemerides of variable stars which were printed annually in the *Vierteljahrsschrift der Astronomischen Gesellschaft* till his death in 1891. Since that time they have been prepared by Dr. Ernst Hartwig of Bamberg. Mr. J. E. Gore published in 1884, in the Proceedings of the Royal Irish Academy, a catalogue of 736 suspected variables and in 1887 a revised catalogue of known variables. Dr. S. C. Chandler of Cambridge, Mass., published

his first catalogue of variables in the *Astronomical Journal* in 1888. His second catalogue appeared in No. 300 of the same publication in 1893. This is the latest and most complete presentation of the subject extant. It contains 260 known variables, all doubtful stars being excluded, the author adhering strictly to the rule that no star shall be admitted whose variation is not attested by at least two reliable observers.

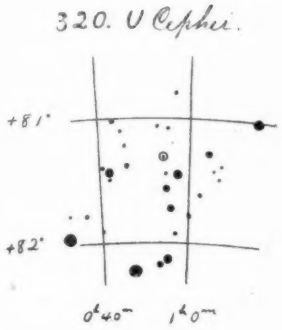
The observations mentioned so far have been entirely visual, but within a few years the photographic plate has been called upon to furnish data in this department. With a given exposure the brighter the star the larger will be its image on the plate, so that photographic magnitudes are commonly deduced by measuring the diameter of the star images with a micrometer. It would follow from this that if plates of the same region were taken from time to time the diameter of the disk of a variable would change its ratio to the diameters of the adjacent stars, so that by measuring a series of plates the variable's light curve could be drawn.

A telescope specially designed for stellar photography is needed for this work and the star disks must be measured by a microscope provided with a micrometer eye-piece in order to attain an accuracy comparable with visual results, so that few amateurs will be able to undertake such investigations. Besides, the time required to expose and develop a plate and make the necessary measurements would suffice to observe a dozen stars visually. The case is different where an extended series of plates, covering a large area may be taken for other purposes. These may also be useful for detecting variables and investigating their actions. The plates taken under the direction of the Harvard College Observatory at Cambridge, Mass., and Arequipa, Peru, are being measured and many new variables have been announced as a result. A very animated discussion has arisen in regard to the weight to which these results are entitled, and the widest differences of opinion are expressed. It is perfectly proper that any new method of astronomical research should be subjected to the severest scrutiny in order that its weak points may be found and strengthened and its proper field assigned. If the visual and photographic results do not agree, all will be interested to learn whether the fault lies in one or the other system, or whether it is due to imperfect work on the part of the observer. Late numbers of *Astronomy and Astro-Physics* and the *Astronomical Journal* contain some of this discussion.

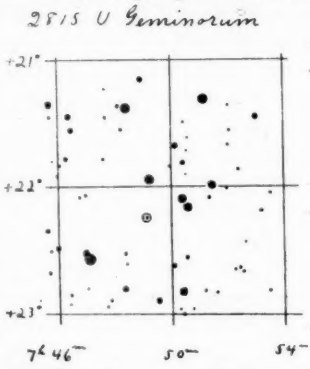
Although good visual work can be done with almost any in-

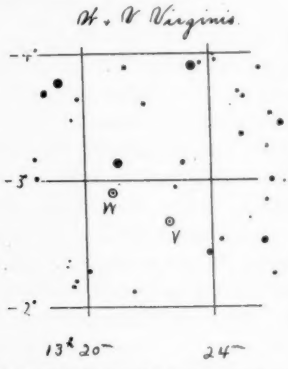
strument from an opera glass to the Yerkes Telescope, yet some forms are cheaper and more convenient than others. The main requirement in variable star work is light gathering power, and this can be had at a comparatively low price in a reflecting telescope. The writer is using a 6.2 inch silver-on-glass reflector of 60 inches focal length, made by J. A. Brashear of Allegheny, Pa., which is a model of convenience. It is equatorially mounted with driving clock and divided circles. The R. A. circle is movable and at the beginning of a night's work is set by pointing on any known star. Any telescopic star can then be found by setting the R. A. and Decl. verniers directly, without the trouble of keeping sidereal time and subtracting to find the hour angle, as must be done where the R. A. circle is fixed. The special advantage of a reflector of short focal length is that the eye-piece can always be brought nearly or quite to the level of the eye and to a horizontal position, so that the observer can look straight forward and be spared the fatigue of crooking his neck into an uncomfortable position. The best observations can always be made near the zenith, but zenith work is very trying with a refractor, while with a reflector it is quite convenient. A six-inch reflector is commonly rated as equal in light gathering power to a five-inch refractor, but the loss of light, about four-tenths of a magnitude, between six and five inches is fully made up by the convenience of zenith observations, since fully four-tenths of a magnitude is absorbed by the atmosphere at a zenith distance of 50°. My mirror has been in use nearly two years without resilvering or even repolishing, and yet I can detect no deterioration.

Charts for five more variables are presented this month. These stars will be in convenient position for evening observation in March and April. 320, U Cephei is one of the most interesting of the Algol type variables; as it decreases very rapidly, losing two magnitudes in about two hours. It is then stationary for about two hours and rises to its usual brightness in the same interval of time. The predicted times of minima are given in the latter part of each number of POPULAR ASTRONOMY. The minima will occur in the evening in March, so that observations will be convenient, and they are needed.



2815, U Geminorum is a wonderful star. Usually the 13th magnitude, once in about three months it rises rapidly to the 9th magnitude, then decreases more slowly to the 13th, the whole operation occupying two or three weeks. Its last maximum occurred 1893, Dec. 8, another may be looked for some time in March or April. There are four 11 to 12 magnitude stars within 10′ of the place, but anything as bright as the 10th magnitude will be the variable. Three inches aperture will be needed to deal with it. The place should be examined every clear evening to catch it on the rise, as it sometimes springs to a maximum in less than two days.





4805, W. Virginis is one of the shortest of the "long period" variables. 4816 and 5675 are now faint but will be increasing in the spring and at their maxima in the early summer. They will require 3 or 4 inches aperture in March, and 2 or 3 inches in April and May.

The severe winter weather has restricted the observation of variables, but when spring opens the work will be comfortable and fascinating. For those who wish to begin observing in March I would recommend the selection of three or four stars from the lists given in this and the preceding numbers, observing them at intervals of a few days and adding to the list as practice gives facility. Three inches aperture will suffice in the spring to deal with 793, 814 and 1855 (see January number), four inches will be needed for 5157 (see February number). These with the five charted in this number, give nine variables available for evening work with small telescopes. Mira, from which some have

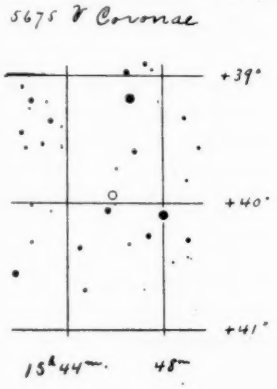


PLATE XVII.

RICHARD ANTHONY PROCTOR.
(1837–1888.)

POPULAR ASTRONOMY, March, 1894.

been expecting so much, is not likely to be visible to the naked eye at its maximum this month (February.)

The following data are taken from Chandlers "Second Catalogue of Variable Stars:"

No.	Star.	1900. R. A.	Decl.	Redness.	Magnitude. Max.	Min.	Period days.
		h m s	° ′				
320	U Cephei	0 53 23	+81 20.2	0	7.1	9.2	2.49
2815	U Geminorum	7 49 10	+22 15.8	0.0	8.9–9.7	13.1	Irreg.
4805	W Virginis	13 20 52	− 2 51.5	0.4	8.7–9.2	9.8–10.4	17.27
4816	V Virginis	13 22 38	− 2 39.2	2.7	8.0–9.0	<13	250.5
5675	V Coronæ	15 45 57	+39 52.3	5.9	7.2–7.7	10.3–12	356.5

MARENGO, ILL.
1894, Feb. 2.

RICHARD A. PROCTOR.

CHARLOTTE R. WILLARD.

At a time when men of affairs as truly as men of science turn with increasing interest to the subject of Astronomy, no small importance attaches to the character and work of the man of whom Professor Young could say, "As an expounder and popularizer of science he stands, I think, unrivaled in English literature."

Richard A. Proctor was born in Chelsea, England, in the year 1837. He was the youngest of four children in a home where learning and refinement greatly influenced the character of later years. Living much in his father's library, at the age of eleven we find him familiar with works of Guizot, Gibbon, Euclid, Shakespeare and Dickens. At the age of nineteen he entered St. John's College, Cambridge. That his attention was not especially turned to mathematics or astronomy during his college career is evident from the following statement from his own pen. "I left Cambridge after taking a respectable degree, with just so much mathematics as I cared to pick up in the time I could spare from literature and from athletic exercises which I thought desirable for my health, then rather delicate. I had read absolutely nothing in astronomy as a science, not imagining then how full of interest that science would one day be to me."

It had been his mother's wish and his own expectation that he should enter the church of England. Finding that this could not

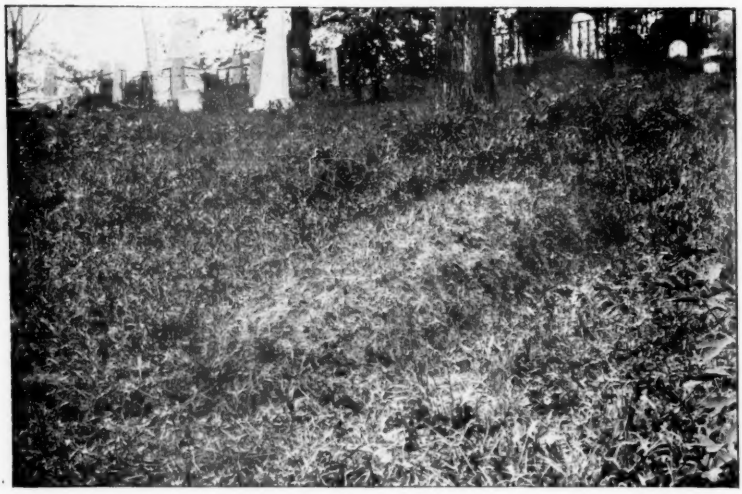
be, he considered Law as his possible profession, but at length became an accountant in a London bank. While still in college he had married an Irish lady, and perhaps that fact led him at this time to make his home near Dublin.

The chance finding of two astronomical books, Nichols' "Architecture of the Heavens" and Mitchell's "Popular Astronomy," at a Glasgow bookstand turned his thoughts in the direction which determined the character of his later work. As his interest in astronomy increased, he tells us that he became possessed of a desire to fit himself to be the teacher of mathematics and astronomy not of schools or popular audiences, but of his eldest son, then two years old.

The first work which Mr. Procter published was a paper on "The Colors of Double Stars," which appeared in the Cornhill Magazine in 1863, and for which the author received fifty dollars. This short paper of nine pages represented six weeks' labor, sometimes not more than four or five lines having been completed in a day. His first book, "Saturn and Its System," was favorably received by scientific men, but proved a financial burden at a time when he especially needed remuneration. The years which followed were full of varied activities. One of his greatest undertakings was the "Charting of 324,000 stars contained in Argelander's Great Catalogue showing the relations of stars down to the 11th magnitude with the Milky Way and its subsidiary branches." He made a careful study of the rotation period of Mars. An idea of the scope of his work may be gained through the following partial list of his writings: Star Distribution, The Construction of the Milky Way, The Distribution of Nebulæ and Star Clusters, The Proper Motion of the Stars, The General Constitution of the Heavens, Geometry of Cycloids, Half-hours with the Telescope and Stars, Light Science for Leisure Hours, Births and Deaths of Worlds, Border Land of Science, The Expanse of Heaven, Myths and Marvels of Astronomy, Our Place Among Infinities, Flowers of the Sky, Poetry of Astronomy; also, Health and Happiness, Watched by the Dead, Mental Phenomena, Luck and Chance, Athletics.

During the last years of his life he was editor of *Knowledge*. Perhaps his most important work was "The Old and New Astronomy" with which he was occupied at the time of his death. It has since been completed by Mr. A. C. Ranyard, the present editor of *Knowledge*.

In 1872 Mr. Procter became secretary of the Royal Astronomical Society of Great Britain, having been previously elected fellow



VIEW OF FIRST PLACE OF INTERMENT.

MONUMENT ERECTED BY GEORGE W. CHILDS TO THE MEMORY OF RICHARD A. PROCTOR, OCTOBER, 1893.

GREENWOOD CEMETERY, BROOKLYN, N. Y.

POPULAR ASTRONOMY, March, 1894.

From Photographs by Wm. Gray, Brooklyn, N. Y.

of that society. Between the years 1873–1884 he made extensive and successful lecturing tours in the United States, Great Britain and the British Colonies.

In 1884, at the close of a long lecture season in the United States, he purchased a home in St. Joseph, Missouri, and a winter residence at Lake Lawn, Florida. In social life Mr. Proctor was a genial, entertaining companion and a firm friend. As a conversationalist he had exceptional gifts.

On the eighth of September, 1888, Mr. Proctor left his winter home, intending to sail for Europe a week later. In New York he was taken violently ill, and two days after his arrival died of yellow fever in one of the hospitals of that city. As there was no opportunity for friends to choose for him a permanent resting place, a temporary interment was made in the undertaker's lot in Greenwood Cemetery. Here his body remained for five years in a wild, uncared-for spot, unnamed and unhonored. His children earnestly desired to provide a suitable lot and monument to honor their father's memory, but had not the necessary means. Interested friends mentioned the matter to Mr. Geo. W. Childs of Philadelphia, and he with characteristic sympathy and liberality made provision for the work. Through the kindness of William Gray, Photographer, 433 Fulton Street, Brooklyn, N. Y., and the advice of Mr. Childs, we are able to present two Greenwood views, the one showing the spot where Mr. Proctor was first buried, the other, his present resting place and the monument erected by Mr. Childs.

As these lines are being written we receive the sad news of Mr. Childs' death. We would pause to join with many on two continents in a tribute of honor to the memory of this man who was the friend of all science, and a source of power in its progress.

Five of Mr. Proctor's children survive him: Mary Proctor, a writer and lecturer on Astronomy who is now a resident of New York City; Agnes M. Proctor, a student in Baird College; John M. Proctor of Portland, Oregon; Richard J. Proctor of Denver, Colorado; and Henry Proctor of Brighton, England. The material for this sketch was kindly provided by Miss Mary Proctor.

A PHOTOGRAPH OF THE PLEIADES AND TWO ASTEROIDS.

H. C. WILSON.

A photographic plate was exposed to the Pleiades for four hours on the night of Jan. 30, by the writer at Goodsell Observatory. The telescope used has an 8-inch objective with three lenses by the Clarks. It was driven by clock-work and the errors produced by irregular driving and refraction were corrected every minute or two by the observer, who was looking through a 5-inch finder at the star Alcyone, keeping it continually bisected by two cross-wires. As a result a very fine picture was obtained of the nebula involving nearly the whole group of bright stars and exhibiting marvelous details of structure resembling those of the great nebula of Orion. The curious straight lines of nebulosity running in some cases from star to star are shown, but are not quite so narrow and hard-edged as shown in the reproductions of previous photographs. The connection of the nebula with the brighter stars of the Pleiades is so obvious that one could hardly doubt it after inspecting the photograph.

All the star images are round and well defined, the very faintest star visible in our 16-inch telescope being easily seen on the plate, while many more can be made out with a magnifying glass.

Among the stars on the plate were found two straight lines, each about 1.2 mm. long, having, aside from their length, the same structure as the star images. These were at once suspected to be minor planets which, because of their motion during the four hours of exposure, impressed lines instead of round dots upon the plate. When these were examined under the microscope a gap was found in the middle of each trail corresponding to the five minutes in the middle of the exposure, when the plate was covered in order that the driving clock might be wound and the telescope readjusted. This completely verified the supposition that the lines were the trials of minor planets. The same asteroids were photographed again, one of them on Feb. 1 and both on Feb. 3. We have measured their approximate positions from the three photographs obtaining the following results:

Asteroid.	Central Time.	R. A.	Decl.
	h m	h m s	° ′ ″
a.	Jan. 30 9 22	3 38 13.2	+23 27 49
	Feb. 1 7 32	3 39 27.5	+23 28 57
	Feb. 3 8 30	3 40 51.6	+23 30 38
b.	Jan. 30 9 22	3 41 24.6	+24 50 29
	Feb. 3 8 30	3 44 17.0	+24 54 43

The brightness of an asteroid is somewhat difficult to estimate from the trail, since the rate of its motion as well as the duration of exposure enters as a factor into the intensity of the trail. As an approximation we may divide the trail into parts equal in length to the diameter of star images of the same intensity. The ratio of brightness will be the number of parts thus obtained. It remains then to determine the brightness of the stars thus used for comparison.

In the present case the asteroid trail *a* was found to be equal to ten stars whose magnitude was estimated to be 14 on Argelander's scale. This according to the usual formula would give the magnitude of *a* as $14 - 2.5 \log 10 = 11.5$. Asteroid *b* was found to be equal to twelve stars of the fifteenth magnitude, its resulting magnitude being $15 - 2.5 \log 12 = 12.3$.

The identification of an asteroid in the list of nearly four hundred is something of a task unless an accurate ephemeris happens to have been computed for that particular one for the time of the observation. A large number of such ephemerides is published in the *Berliner Jahrbuch*. Each covers, however, only one month near the time when the planet is at opposition, and in the present case the region photographed was not opposite the Sun. Another table in the *Jahrbuch* gives the time of opposition, and the right ascension and declination at that time, of each minor planet. A little study of this table will generally enable the observer to exclude all but five or six of the known asteroids as too far from the given region. For the remaining number is necessary to calculate the latitude and longitude or right ascension and declination of each from the elements of their orbits, in order to compare them with the same coordinates measured from the photograph. Where the elements have been brought up to date, this process is not so very difficult, but when the elements given belong to an epoch several years back it is necessary to calculate the perturbations of the orbits by the large planets, a process involving much labor.

In this instance the asteroids Nos. (33), (184), (196), (203), (207), (235) and (309) were found by inspection to be somewhere in the vicinity of the region of sky photographed. The calculation of the latitudes and longitudes, however, showed that only

(203) was within the region of the photograph, its place falling within 3^m of longitude and 5′ of latitude of that of *a*. The two were therefore assumed to be the same. The asteroid *b* is probably a new one, although it is possible that perturbations which were not allowed for in reducing the elements of (207) and (309) from 1889 and 1890 respectively to 1894 may have sufficiently changed their orbits to bring one or the other of them into the place of *b*.

TWO NEW VARIABLE STARS.*

M. FLEMING.

A recent examination of the photographs of stellar spectra forming part of the Henry Draper Memorial work at the Harvard College Observatory, Cambridge, has led to the discovery that the stars A.G.C. 157 in R.A. $0^h\ 10^m.4$, Dec. $-32°\ 36'$, Magn. 8, and B.D. $+1°\ 3417$ in R.A. $17^h\ 14^m.5$, Dec. $+1°\ 37'$, Magn. 9.5 are variable. The first named star is in the constellation Sculptor and its magnitude varies from 6.5 to 10. The second is in the constellation Ophiuchus and it varies from the magnitude 8.5 to 12.5. The approximate positions for 1900 are those given above.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Feb. 13, 1894.

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury will be "morning star" during April, and will be at greatest elongation, west from the Sun 27° 40′, on the tenth of the month. Mercury will be in conjunction with the Moon April 3 at $5^h\ 37^m$ P. M. central time.

Venus is also "morning star" and is nearing greatest elongation west from the Sun. The greatest distance from the Sun, 46° 10′, will be reached on the morning of April 27. This will be a favorable month, so far as position is concerned, for the study of the surface markings of Venus, although the fact that she is only visible in the morning will be a drawback to all but the most enthusiastic amateurs. On the morning of April 5 Venus will be near the star α Aquarii, conjunction in right ascension occurring at $2^h\ 17^m$ A. M. central time. Venus will then be 19′ south of the star. The illuminated portion of her disc will increase during the month from one third to one half, while her brilliancy will decrease in the ratio of 195 to 139.

* Communicated by Edward C. Pickering, Director of Harvard College Observatory.

Mars improves a little in position during April, but it will not yet pay to spend much time in trying to observe this planet. He will move eastward and northward through the center of the constellation Capricornus. As he is brighter than any of the stars in the constellation it would not be difficult to identify him without the ruddy color which makes him so conspicuous. Mars will be in conjunction with the Moon April 29 at 1 A. M.

Jupiter will be pretty low in the west during the observing hours of April, but some satisfactory views may yet be obtained. He is moving slowly eastward south of the Pleiades. Jupiter will be in conjuction with the Moon, 5° south, April 9 at 5 A. M.

Saturn and *Spica* (α Virginis) make a fine pair in the south in the morning. They are nearly equal in brilliancy but differ a little in color, Saturn having a golden hue while Spica is bluish white. Saturn is retrograding, that is moving westward, and at the end of April will be almost directly north of Spica. He will be at opposition April 11 at noon. The moon will pass by Saturn, 4° to the south, April 10 at $9^h\ 28^m$ P. M.

Uranus is toward the southeast from Saturn in the constellation Libra. On the morning of the 27th at $7^h\ 11^m$ he will be in conjunction with the second magnitude star α Libræ, being only 4′ north of the brighter component of that star which is a wide double. The motion of Uranus is so slow that he will be in the vicinity of the star for several days, so that this will be an excellent opportunity for the amateur to be sure that he has seen this planet. Note the green color and the visibility of a definite disc.

Neptune may be observed in the early evening but has past the most favorable position. He is about half way between ι and ε in the constellation Taurus.

Planet Tables for April.

[The times given are local time for Northfield. To obtain Standard Times for Place in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
		MERCURY.			
Apr. 5	23 21.7	− 5 35	4 47 A. M.	10 25.9 A. M.	4 05 P. M.
15	23 58.8	− 2 52	4 31 "	10 23.5 "	4 16 "
25	0 49.0	+ 2 20	4 22 "	10 34.4 "	4 47 "
		VENUS.			
Apr. 5	22 12.1	− 8 36	3 47 A. M.	9 16.6 A. M.	2 46 P. M.
15	22 44.8	− 6 53	3 34 "	9 09.7 "	2 46 "
25	23 20.6	− 4 22	3 20 "	9 06.1 "	2 52 "
		MARS.			
Apr. 5	20 33.6	− 19 56	2 58 A. M.	7 38.3 A. M.	12 19 P. M.
15	21 02.7	− 18 14	2 40 "	7 28.0 "	12 16 "
25	21 31.1	− 16 18	2 20 "	7 17.1 "	12 14 "
		JUPITER.			
Apr. 5	3 54 5	+ 19 43	7 32 A. M.	2 58.0 P. M.	10 24 P. M.
15	4 02.9	+ 20 09	6 59 "	2 27.0 "	9 55 "
25	4 11.9	+ 20 35	6 26 "	1 56.5 "	9 27 "
		SATURN.			
Apr. 5	13 26.5	− 6 06	6 49 P. M.	12 28.3 A. M.	6 07 A. M.
15	13 23.6	− 5 48	6 05 "	11 46.1 P. M.	5 27 "
25	13 20.8	− 5 32	5 22 "	11 04.0 "	4 46 "

URANUS.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Apr. 5	14 48.4	− 15 47	8 51 P. M.	1 49.9 A. M.	6 49 A. M.
15	14 46.9	− 15 40	8 09 "	1 09.1 "	6 09 "
25	14 45.3	− 15 33	7 28 "	12 28.2 "	5 28 "

NEPTUNE.

Apr. 5	4 40.0	+ 20 41	8 12 A. M.	3 43.3 P. M.	11 14 P. M.
15	4 41.0	+ 20 44	7 34 "	3 05.1 "	10 36 "
25	4 42.3	+ 20 46	6 56 "	2 27.0 "	9 58 "

THE SUN.

Apr. 5	0 58.7	+ 6 16	5 34 A. M.	12 02.6 P. M.	6 31 P. M.
15	1 35.5	+ 9 57	5 17 "	11 59.9 A. M.	6 43 "
25	2 12.8	+ 13 22	5 00 "	11 57.8 "	6 55 "

THE MOON.

Apr. 1	21 26.4	− 19 30	4 03 A. M.	8 46.6 A. M.	1 39 P. M.
3	23 03.0	− 8 40	4 35 "	10 15.2 "	4 08 "
5	0 38.8	+ 4 12	5 21 "	11 42.8 "	6 19 "
7	2 22.6	+ 16 52	6 02 "	1 18.4 P. M.	8 51 "
9	4 22.8	+ 26 06	7 01 "	3 10.5 "	11 33 "
11	6 36.6	+ 28 28	8 43 "	5 16.0 "	1 45 A. M.
13	8 45.5	+ 22 53	11 12 "	7 16.6 "	3 06 "
15	10 37.5	+ 11 51	1 50 P. M.	9 00.5 "	3 54 "
17	12 17.5	− 1 19	4 19 "	10 32.4 "	4 32 "
19	13 55.1	− 13 51	6 42 "	12 01.9 A. M.	5 10 "
21	15 38.2	− 23 27	9 04 "	1 36.8 "	6 02 "
23	17 28.7	− 28 16	11 16 "	3 19.1 "	7 20 "
26	19 20.3	− 27 22	12 57 A. M.	5 02.6 "	9 11 "
28	21 05.3	− 21 18	2 04 "	6 39.2 "	11 23 "
30	22 41.6	− 11 17	2 48 "	8 07.6 "	1 38 P. M.

Phases and Aspects of the Moon.

Central Time.

	d	h m
New Moon	Apr. 5	10 00 P. M.
Perigee	" 10	9 40 P. M.
First Quarter	" 12	6 32 P. M.
Full Moon	" 19	9 02 P. M.
Apogee	" 26	1 55 A. M.
Last Quarter	" 27	9 21 P. M.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

		h m			h m			h m
Apr.	1	7 26 P. M.	Apr.	11	5 40 P. M.	Apr.	21	3 54 P. M.
	2	3 17 "		12	11 27 "		22	9 41 "
	3	9 04 "		13	7 18 "		23	5 32 "
	4	4 55 "		14	3 09 "		24	11 19 "
	5	10 42 "		15	8 56 "		25	7 10 "
	6	6 33 "		16	4 47 "		26	3 02 "
	7	2 24 "		17	10 34 "		27	8 48 "
	8	8 11 "		18	6 25 "		28	4 40 "
	9	4 02 "		19	2 16 "		29	10 26 "
	10	9 49 "		20	8 03 "		30	6 18 "

Jupiter's Satellites for April.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.		III.	
II.		IV.	No Eclipse.

Configuration at 7h for an Inverting Telescope.

Day.	West	East.
1	○1· 4· ·3 ·2 ○	
2	4· .○3 ·1 ·2	
3	·4 1· ○2· ·3	
4	·4 2· ○ ·1 3·	
5	·4 ·1 ○ 3·	·2●
6	3· ·4 ○ ·1 2·	
7	3· 2· ·1 ○ ·4	
8	·3 ·2 ○1· ·4	
9	·3 ○ ·2 ·4	·1●
10	1· ○ 2· ·3 ·4	
11	2· ○ ·1 ·3 4·	
12	1· ○ 3· 4·	·2●
13	3· ○ 1· 2· 4·	
14	3· 2· ·1 ○ 4·	
15	·3 ·2 4· ○ 1·	
16	4· ·3 ·1○ ·2	
17	·4 1·○ 2· ·3	
18	4· 2· ○ ·1 ·3	
19	·4 1· ·2 ○ 3·	
20	○3· ·4 ○ ·1 ·2	
21	·4 3· ·1 2· ○	
22	·3 ·4 ·2 ○ 1·	
23	·3 ·1 ·4 ○ 2·	
24	○1· ○ ·32· ·4	
25	2· ○ ·1 ·3 ·4	
26	1· ·2 ○ 3· 4·	
27	○ 3· ·1 ·2 ·4	
28	○2· 3· 1· ○ 4·	
29	3· ·2 ○ 1· 4·	
30	·3 ·1 ○ ·2 4·	

Phenomena of Jupiter's Satellites.

Central Time.

		h	m					h	m			
Apr.	1	5	54	P. M.	I	Tr. In.	Apr. 11	1	47	A. M.	II	Sh. In.
		6	54	"	I	*Sh. In.		2	28	"	II	Tr. Eg.
		8	08	"	I	*Tr. Eg.		4	11	"	II	Sh. Eg.
		9	07	"	I	Sh. Eg.		11	47	"	I	Oc. Dis.
	2	2	01	A. M.	II	Oc. Dis.		2	50	P. M.	I	Ec. Re.
		6	21	"	II	Ec. Re.	12	8	56	A. M.	I	Tr. In.
		3	16	P. M.	I	Oc. Dis.		9	47	"	I	Sh. In.
		6	26	"	I	*Ec. Re.		11	09	"	I	Tr. Eg.
		7	24	"	III	*Oc. Dis.		12	00	M.	I	Sh. Eg.
		9	37	"	III	Oc. Re.		6	13	P. M.	II	*Oc. Dis.
		11	32	"	III	Ec. Dis.		10	17	"	II	Ec. Re.
	3	1	24	A. M.	III	Ec. Re.	13	6	17	A. M.	I	Oc. Dis.
		12	25	P. M.	I	Tr. In.		9	19	"	I	Ec. Re.
		1	23	"	I	Sh. In.		2	05	P. M.	III	Tr. In.
		2	38	"	I	Tr. Eg.		4	19	"	III	Tr Eg
		3	36	"	I	Sh. Eg.		5	31	"	III	Sh. In.
		9	14	"	II	Tr. In.		7	38	"	III	*Sh. Eg
		11	10	"	II	Sh. In.	14	3	26	A. M.	I	Tr. In.
		11	40	"	II	Tr. Eg.		4	16	"	I	Sh. In.
	4	1	34	A. M.	II	Sh. Eg.		5	39	"	I	Tr. Eg.
		9	46	"	I	Oc. Dis.		6	29	"	I	Sh. Eg.
		12	54	P. M.	I	Ec. Re.		1	26	P. M.	II	Tr. In.
	5	6	55	A. M.	I	Tr. In.		3	05	"	II	Sh. In.
		7	51	"	I	Sh. In.		3	52	"	II	Tr. Eg.
		9	08	"	I	Tr. Eg.		5	30	"	II	Sh. Eg.
		10	05	"	I	Sh. Eg.	15	12	47	A. M.	I	Oc. Dis
		3	25	P. M.	II	Oc. Dis.		3	47	"	I	Ec. Re.
		7	39	"	II	*Ec. Re.		9	56	P. M.	I	Tr. In.
	6	4	16	A. M.	I	Oc. Dis.		10	44	"	I	Sh. In.
		7	23	"	I	Ec. Re.	16	12	10	A. M.	I	Tr. Eg.
		9	41	"	III	Tr. In.		12	58	"	I	Sh. Eg.
		11	54	"	III	Tr. Eg.		7	37	"	II	Oc. Dis.
		1	31	P. M.	III	Sh. In.		11	35	"	II	Ec. Re.
		3	36	"	III	Sh. Eg.		7	18	P. M.	I	*Oc. Dis.
	7	1	25	A. M.	I	Tr. In.		10	16	"	I	Ec. Re.
		2	20	"	I	Sh. In.	17	4	13	A. M.	III	Oc. Dis.
		3	38	"	I	Tr. Eg.		6	28	"	III	Oc. Re.
		4	34	"	I	Sh. Eg.		7	34	"	III	Ec. Dis.
		10	38	"	II	Tr. In.		9	28	"	III	Ec. Re.
		12	29	P. M.	II	Sh. In.		4	26	P. M.	I	Tr. In.
		1	04	"	II	Tr. Eg.		5	13	"	I	Sh. In.
		2	53	"	II	Sh. Eg.		6	40	"	I	*Tr. Eg.
		10	46	"	I	Oc. Dis.		7	27	"	I	*Sh. Eg.
	8	1	52	A. M.	I	Ec. Re.	18	2	50	A. M	II	Tr. In.
		7	55	P. M.	I	*Tr. In.		4	24	"	II	Sh. In.
		8	49	"	I	Sh. In.		5	17	"	II	Tr. Eg.
		10	09	"	I	Tr. Eg.		6	48	"	II	Sh. Eg.
		11	03	"	I	Sh. Eg.		1	48	P M.	I	Oc. Dis.
	9	4	49	A. M.	II	Oc. Dis.		4	45	"	I	Ec. Re.
		8	58	"	II	Ec. Re.	19	10	57	A. M.	I	Tr. In.
		5	16	P. M.	I	Oc. Dis.		11	42	"	I	Sh. In.
		8	21	"	I	*Ec. Re.		1	11	P. M.	I	Tr. Eg.
		11	48	"	III	Oc. Dis.		1	55	"	I	Sh. Eg.
	10	2	02	A. M.	III	Oc. Re.		9	02	"	II	Oc. Dis.
		3	33	"	III	Ec. Dis.	20	12	54	A. M.	II	Ec. Re.
		5	26	"	III	Ec. Re.		8	18	"	I	Oc. Dis.
		2	25	P. M.	I	Tr. In.		11	14	"	I	Ec. Re.
		3	18	"	I	Sh. In.		6	32	P. M.	III	*Tr. In.
		4	39	"	I	Tr. Eg.		8	48	"	III	Tr. Eg.
		5	31	"	I	Sh. Eg.		9	34	"	III	Sh. In.
	11	12	02	A. M.	II	Tr. In.		11	41	"	III	Sh. Eg.

Apr.	21	5	27	A. M.	I	Tr.	In.	Apr.	25	26	40	P. M.	I	*Ec.	Re.
		6	11	"	I	Sh.	In.		26	12	58	"	I	Tr.	In.
		7	41	"	I	Tr.	Eg.			1	37	"	I	Sh.	In.
		8	24	"	I	Sh.	Eg.			3	12	"	I	Tr.	Eg.
		4	15	P. M.	II	Tr.	In.			3	50	"	I	Sh.	Eg.
		5	42	"	II	Sh.	In.			11	51	"	II	Oc.	Dis.
		6	41	"	II	*Tr.	Eg.		27	3	31	A. M	II	Ec.	Re.
		8	07	"	II	Sh.	Eg.			10	20	"	I	Oc.	Dis.
	22	2	49	A. M.	I	Oc.	Dis.			1	09	P. M.	I	Ec.	Re.
		5	43	"	I	Ec.	Re.			11	00	"	III	Tr.	In.
		11	57	P. M.	I	Tr.	In.		28	1	16	A. M.	III	Tr.	Eg.
	23	12	39	A. M.	I	Sh.	In.			1	34	"	III	Sh.	In.
		2	11	"	I	Tr.	Eg.			3	43	"	III	Sh.	Eg.
		2	53	"	I	Sh.	Eg.			7	29	"	I	Tr.	In.
		10	27	"	II	Oc.	Dis.			8	06	"	I	Sh.	In.
		2	13	P. M.	II	Ec.	Re.			9	43	"	I	Tr.	Eg.
		9	19	"	I	Oc.	Dis.			10	19	"	I	Sh.	Eg.
	24	12	11	A. M.	I	Ec.	Re.			7	04	P M.	II	*Tr.	In.
		8	40	"	III	Oc.	Dis.			8	18	"	II	Sh.	In.
		10	55	"	III	Oc.	Re.			9	31	"	II	Tr.	Eg.
		11	34	"	III	Ec.	Dis.			10	43	"	II	Sh.	Eg.
		1	30	P. M.	III	Ec.	Re.		29	4	50	A. M.	I	Oc.	Dis.
		6	28	"	I	*Tr.	In.			7	38	"	I	Ec.	Re.
		7	08	"	I	*Sh.	In.		30	1	59	"	I	Tr.	In.
		8	42	"	I	Tr.	Eg.			2	34	"	I	Sh.	In.
		9	22	"	I	Sh.	Eg.			4	13	"	I	Tr.	Eg
	25	5	39	A. M.	II	Tr.	In.			4	48	"	I	Sh.	Eg.
		7	00	"	II	Sh.	In.			1	17	P. M.	II	Oc.	Dis.
		8	06	"	II	Tr.	Eg.			4	50	"	II	Ec.	Re.
		9	25	"	II	Sh.	Eg.			11	21	"	I	Oc.	Dis.
		3	49	P. M.	I	Oc.	Dis.	May	1	2	06	A. M.	I	Ec.	Re.

NOTE —In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc. denotes occultation; Tr., transit of the satellite; Sh., transit of the shadow; * Visible at Washington.

Annular Eclipse of the Sun, April 5, 1894.—This will not be visible in the United States. The path of the annular eclipse passes from a point in the Persian Gulf, across Hindostan and China, along the east coast of Siberia, ending in Alaska. It will be visible as a partial eclipse throughout Asia, north-eastern Europe and parts of the Indian and Pacific Oceans.

ELEMENTS OF THE ECLIPSE.

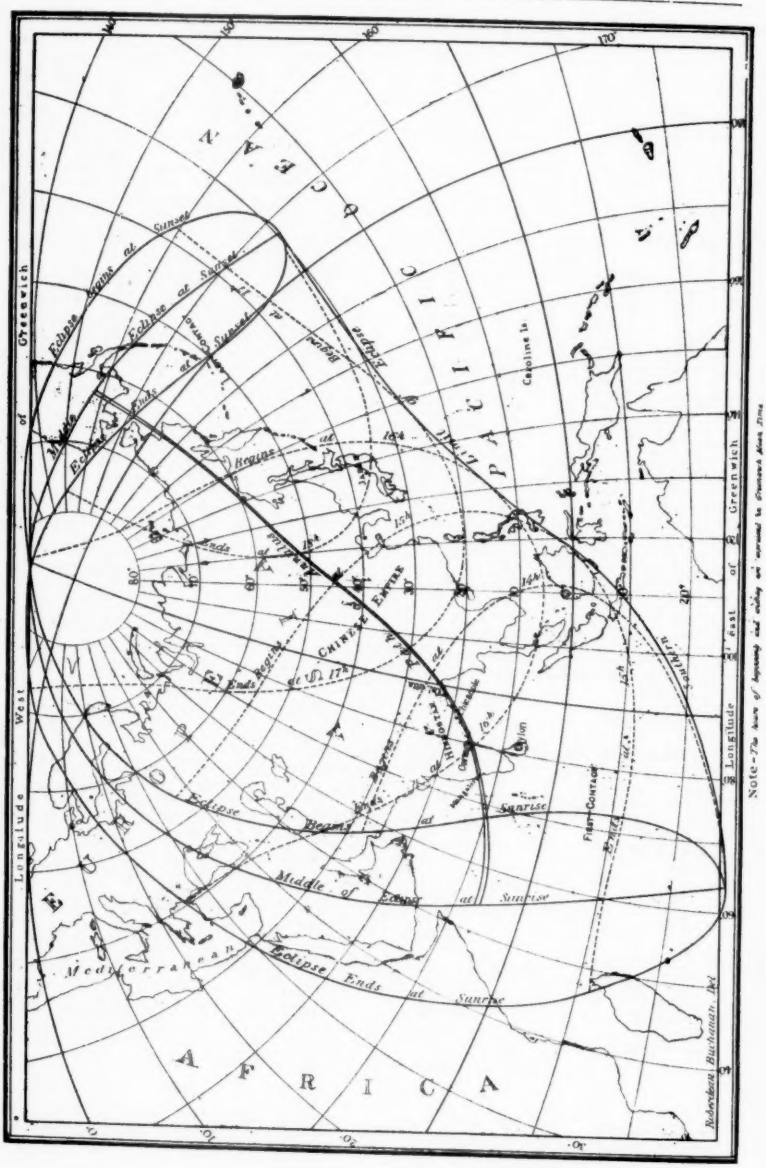
Greenwich mean time of conjunction in right ascension
April 5, 16^h 27^m $39^s.2$

Sun and Moon's R. A.	1^h 00^m $16^s.90$	Hourly motions	$9^s.14$ and	$121^s.28$	
Sun's declination	6° 26′ 11″.6 N.	Hourly motion	0′	56″.7	N.
Moon's declination	7 03 48 .5 N.	Hourly motion	15	53 .7	N.
Sun's equa. hor. par.	8 .6	Sun's true diameter	15	58 .6	
Moon's equa. hor. par.	57 52 .5	Moon's true diameter	15	45 .5	

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Time.	Long. from Greenwich.	Latitude.
Eclipse begins April 5,	13^h $15^m.9$	72° 24′.2 E.	6° 33′.6 S.
Central eclipse begins	14 24 .0	53 51 .8 E.	6 47 .4 N.
Central eclipse at noon	16 27 .7	113 42 .5 E.	47 22 .3 N.
Central eclipse ends	17 23 .3	157 30 .7 W.	62 47 .5 N.
Eclipse ends	18 31 .5	179 34 .2 W.	49 44 .5 N.

ANNULAR ECLIPSE OF APRIL 5TH 1894.



Elongations of the Satellites of Saturn.

[In the diagram the points marked 0 are those of eastern elongation of the several satellites. Their positions at intervals of one day after eastern elongation are indicated by the symbols 1*d*, 2*d*, etc.]

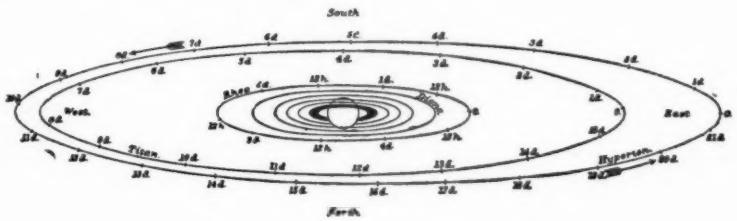


DIAGRAM OF THE APPARENT ORBITS OF SATURN'S SATELLITES.

MIMAS.

		h		
Apr.	4	2.7	A. M.	E
	5	1.3	"	E
	5	11.9	P. M.	E
	6	10.5	"	E
	7	9.1	"	E
	8	7.7	"	E
	9	6.3	"	E
	10	4.9	"	E
	11	3.5	"	E
	12	2.9	A. M.	W
	13	1.5	"	W
	14	12.1	"	W
	14	10.8	P. M.	W
	15	9.4	"	W
	16	8.0	"	W
	17	6.6	"	W
	18	5.2	"	W
	19	3.8	"	W
	20	3.2	A. M.	E
	21	1.8	"	E
	22	12.4	"	E
	22	11.0	P. M.	E
	23	9.6	"	E
	24	8.2	"	E
	25	6.8	"	E
	26	5.4	"	E
	27	4.0	"	E
	28	2.6	"	E
	29	2.0	A. M.	W
	30	12.6	"	W
	30	11.3	P. M.	W

ENCELADUS.

		h		
Apr.	2	12.3	P. M.	E
	3	9.1	"	E
	5	6.0	A. M.	E
	6	2.9	P. M.	E
	7	11.8	"	E

ENCELADUS Cont.

		h		
Apr.	9	8.7	A. M.	E
	10	5.5	P. M.	E
	12	2.4	A. M.	E
	13	11.3	"	E
	14	8.2	"	E
	16	5.1	A. M.	E
	17	1.9	P. M.	E
	18	10.8	"	E
	20	7.7	A. M.	E
	21	4.6	P. M.	E
	23	1.5	A. M.	E
	24	10.3	"	E
	25	7.2	P. M.	E
	27	4.1	A. M.	E
	28	1.0	P. M.	E
	29	9.9	"	E

TETHYS.

		h		
Apr.	1	4.7	P. M.	E
	3	2.0	"	E
	5	11.3	A. M.	E
	7	8.5	"	E
	9	5.8	"	E
	11	3.1	"	E
	13	12.4	"	E
	14	9.7	P. M.	E
	16	7.0	"	E
	18	4.3	"	E
	20	1.6	"	E
	22	10.9	"	E
	24	8.2	"	E
	26	5.5	"	E
	28	2.8	"	E
	30	12.1	"	E

DIONE.

		h		
Apr.	2	7.9	P. M.	E
	5	1.6	"	E
	8	7.3	A. M.	E

DIONE Cont.

		h		
Apr.	11	12.9	A. M.	E
	13	6.6	P. M.	E
	16	12.3	"	E
	19	6.0	A. M.	E
	21	11.6	P. M.	E
	24	5.3	"	E
	27	11.0	A. M.	E
	30	4.7	"	E

RHEA.

		h		
Apr.	3	12.6	A. M.	E
	7	1.0	P. M.	E
	12	1.4	A. M.	E
	16	1.7	P. M.	E
	21	2.1	A. M.	E
	25	2.5	P. M.	E
	30	2.9	A. M.	E

TITAN.

		h		
Apr.	1	5.4	A. M.	I
	5	8.4	"	W
	9	10.3	"	S
	13	5.0	"	E
	17	2.5	"	I
	21	5.5	"	W
	25	7.8	"	S
	29	2.5	"	E

HYPERION.

		h		
Apr.	1	4.0	A. M.	E
	7	11.2	"	I
	12	6.2	P. M.	W
	17	3.9	A. M.	S
	22	8.3	"	E
	28	3.9	P. M.	I

IAPETUS.

		h		
Apr.	9	9.0	A. M.	E
	27	9.2	"	I

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A.....0h 52m 32s
Decl.....+81° 17′
Period.....2*d* 11h 50m

Apr.		
	2	5 A. M.
	4	4 P. M.
	7	4 A. M.
	9	4 P. M.
	12	4 A. M.
	14	4 P. M.
	17	3 A. M.
	19	3 P. M.
	22	3 A. M.
	24	3 P. M.
	27	3 A. M.
	29	3 P. M.

ALGOL.

R. A.....3h 1m 1s
Decl.....+ 40° 32′
Period.....2*d* 20h 49m

Apr.		
	3	8 P. M.
	6	5 "
	9	2 "
	12	11 A. M.
	15	8 "
	18	4 "
	21	1 "
	23	10 P. M.
	26	7 "

R CANIS MAJORIS.

R. A..... 7h 14m 30s
Decl..... —16° 11′
Period..... ..1*d* 3h 16m

Apr.		
	1	2 P. M.
	2	5 "
	3	9 "
	4	12 midn.
	6	3 A. M.
	7	6 "
	8	10 "
	9	1 P. M.
	10	4 "
	11	8 "
	12	11 "
	14	2 A. M.
	15	5 "
	16	8 "
	17	12 noon.
	18	3 P. M.
	19	6 "
	20	10 "
	22	1 A. M.
	23	4 "
	24	7 "
	25	11 "
	26	2 P. M.
	27	5 "
	28	8 "
	29	12 midn.

S CANCRI.

R. A..... 8h 37m 39s
Decl.....+ 19° 26′
Period.....9*d* 11h 38m

Apr.		
	3	12 midn.
	13	12 noon.
	23	12 midn.

S ANTLIÆ.

(Every third minimum.)

R. A..... 9h 27m 30s
Decl.....— 28° 09′
Period..... 0*d* 7h 47m

Apr.		
	1	8 P. M.
	2	7 "
	3	7 "
	4	6 "
	5	5 "
	6	4 "
	7	4 "
	8	3 "
	9	2 "
	10	2 "
	11	1 "
	12	12 noon.
	13	12 noon.
	14	10 A. M.
	15	4 "
	16	10 "
	17	9 "
	18	9 "
	19	8 "
	20	7 "
	21	7 "
	22	6 "
	23	5 "
	24	5 "
	25	4 "
	26	3 "
	27	3 "
	28	2 "
	29	1 "
	30	1 "

δ LIBRÆ.

R. A..... ..14h 55m 06s
Decl..... — 8° 05′
Period..... 2*d* 07h 51m

Apr.		
	2	7 P. M.
	5	3 A. M.
	7	11 "
	9	7 P. M.
	12	3 A. M.
	14	10 "
	16	6 P. M.
	19	2 A. M.
	21	10 "
	23	6 P. M.
	26	2 A. M.
	28	10 "
	30	6 P. M.

U CORONÆ.

R. A 15h 13m 43s
Decl..... + 32° 03′
Period..... 3*d* 10h 51m

Apr.		
	4	3 A. M.
	7	2 P. M.
	11	1 A. M.
	14	12 noon
	17	10 P. M.
	21	9 A. M.
	24	8 P. M.
	28	7 A. M.

U OPHIUCHI.

R. A.....17h 10m 56s
Decl..... + 1° 20′
Period..... 0*d* 20h 08m

Apr.		
	1	6 A. M.
	2	2 "
	2	10 P. M.
	3	6 "
	4	1 "
	5	11 A. M.
	6	7 "
	7	3 "
	7	11 P. M.
	8	8 "
	9	4 "
	10	12 noon
	11	8 A. M.
	12	4 "
	12	12 midn.
	13	8 P. M.
	14	4 "
	15	1 "
	16	9 A. M.
	17	5 "
	18	1 "
	18	9 P. M.
	19	5 "
	20	1 "
	21	9 A. M.
	21	6 "
	23	2 "
	23	10 P. M.
	24	6 "
	25	2 "
	26	10 A. M.
	27	6 "
	28	2 "
	28	11 P. M.
	29	7 "
	30	3 "

Y CYGNI.

R. A.....20h 47m 40s
Decl..... + 34° 15′
Period..... 1*d* 11h 57m

Apr.		
	1	1 P. M.
	3	1 A. M.
	4	1 P. M.

Y CYGNI CONT.		Y CYGNI CONT.		Y CYGNI CONT.	
Apr. 6	1 A. M.	Apr. 15	1 A. M.	Apr. 24	1 A. M.
7	1 P. M.	16	1 P. M.	25	1 P. M.
9	1 A. M.	18	1 A. M.	27	1 A. M.
10	1 P. M.	19	1 P. M.	28	1 P. M.
12	1 A. M.	21	1 A. M.	30	1 A. M.
13	1 P. M.	22	1 P. M.		

Occultations Visible at Washington.

Date 1894.	Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N pt.	EMERSION Washington M. T.	EMERSION Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
Apr. 8	9 Tauri	7	8 17	74	9 12	266	0 55
10	136 Tauri	5	12 35	160	12 55	209	0 20
12	ω^2 Cancri	6	12 57	65	13 22	333	0 25

Maxima and Minima of Variable Stars.

	MAXIMA		MINIMA	
April	1	R Herculis	5	X Bootis
	2	U Virginis	5	W Scorpii
	10	R Arietis	6	S Cygni
	11	V Leonis	13	R Canum Ven.
	12	X Scorpii	15	U Monocerotis
	14	V Capricorni	15	U Bootis
	16	L^2 Puppis	18	S Ursæ Maj.
	18	V Capricorni	19	R Lyræ
	20	U Capricorni	23	R Ursæ Maj.
			23	S Vulpeculæ
			25	S Piscium
			28	T Arietis

New Asteroids 1894 AQ, AR and AS.—These were discovered photographically by Charlois at Nice on the nights of Jan. 8 and 10. Their positions were as follows:

		G. M. T.	R. A.	Decl.	Daily motion	Mag.
		h m	h m s	° ′	′ ′	
1894	AQ Jan. 8	9 25	7 21 48	+ 20 01	− 48 + 1	13
	AR 8	9 25	7 36 12	+ 24 10	− 60 + 4	13
	AS 10	10 45	8 33 16	+ 17 48	− 44 + 6	12.5

Numeration of the Asteroids of 1893.—Dr. A. Berberich who prepares the tables of Minor Planets for the *Berliner Jahrbuch* sends us the following note:

"You gave recently the numeration of the Minor Planets from *Astronomische Nachrichten* 3194. You will have seen, by *Bulletin Astronomique* Nov. and *Astr. Nach.* 3201, that No. 359 must be omitted, as 1893 L proves to be identical with (89) Julia. I took every precaution in order to avoid similar errors in computing the dates of oppositions for 1894, but it is impossible to vouch for the exactness of all of 240 ephemerides, only 60 of which are computed in duplicate.

"The later planets of 1893 receive the following numbers.

		Discovered by	
1893	AJ = 373	Charlois	Sept. 15
	AK = 374	"	Sept. 18
	AL = 375	"	Sept. 18
	AM = 376	"	Sept. 18
	AN = 377	"	Sept. 20
	AP = 378	"	Dec. 6

"The name 'Chicago,' chosen at the astronomical Congress for a minor planet, has been conferred by Professor M. Wolf upon the planet (334). This planet presents a good means of determining the mass of Jupiter. It undergoes very remarkable perturbations by that great planet. The planets (153) Hilda, (190) Ismene, (279) Thule and (361) are also exposed to considerable perturbations, but only in future times. A conjunction of Hilda and Jupiter some years ago coincided with the perihelion passage of Hilda so that the distance of the two bodies has been at a maximum.

"I find that the Watson planet (175) Andromache, rediscovered in 1893 by Charlois and photographed in 1892 by Wolf, was in proximity to Jupiter in 1886-87, being near aphelion and moving very slowly. As the period of (175) is nearly one-half of that of Jupiter that conjunction will be repeated every 11-12 years, in about the same position. The effect will be a retardation of the mean motion, probably of large amount. I think the moderately distant planets are of greater value for the determination of Jupiter's mass than those very remote, like Hilda, since the conjunctions with Jupiter are much more frequent. Thus in one century we may observe 8 conjunctions of Andromache but only 4 of Hilda and scarcely 3 of Thule, with Jupiter."

PRACTICAL SUGGESTIONS.

22. Why do astronomers use high magnifying power in looking at the fixed stars, since it is held that they are mere points of light without any sensible disc?

Answer.—It is true that all stars (except our Sun) are so far distant that the largest telescope has not power to show any real disc. What is seen is an intensely lighted spot, not a point of light, which astronomers call a spurious or diffraction disc. This false disc is probably due both to irradiation and the wave nature of light. Bright bodies on a dark background always appear larger than they really are however carefully measured; this effect is called irradiation.

In studying the stars by the aid of the telescope, the observer may wish to learn their colors, magnitudes, spectra, motions, binary nature or some other characteristic, and this spurious disc and its light are the given quantities in the problem. The disc consists of a bright center rapidly fading out to darkness at its edges, which is surrounded by a series of colored rings, the smallest of whic only is seen easily by those accustomed to observe the stars, yet any one may see it when attention is called to it under favorable circumstances. The diameter of this false disk varies inversely as the aperture or size of the object-glass, a fact which is somewhat troublesome to those who have not studied the wave theory of light. It may be here sufficient to say that astronomers can calculate the size of this ring-and-disc system from the known lengths of the waves of light and the diameter of the object-glass of the telescope, and that their computed and observed sizes agree very precisely. Now, if an observer wishes to examine the colors of bright stars even in good "seeing," he will ordinarily use low powers or none at all, because he has light enough at command. But when he wishes to try the fainter stars the case is different and magnifying power is needed. To understand how the telescope works in this regard, point it to the sky illuminated by daylight and notice the small circle of light on the lens of the eye-piece. That is the image of the object-glass. The ratio of the diameter of the object-glass to that of the small circle is the magnifying power of that particular eye-piece. The same eye-piece on telescopes of different sizes will cause this light

circle to vary in size and brightness. Let s be the diameter of the circle, o the diameter of the object-glass and e the diameter of the pupil of the eye; then $\frac{o}{s}$ is the magnifying power. If $s = e$ the eye can use all the light from the celestial body if not too bright, which passes through the object-glass except small losses by reflection and absorption. The amount of light so received is $\left(\frac{o}{e}\right)^2$ times that which would be received by the naked eye. Also the apparent area of the circle is magnified $\left(\frac{o}{e}\right)^2$ which, since $s = e$, is the same as the increase of light. Hence brightness of the circle is the same as the naked illumination of the sky. If s is greater than e it can be shown that the same conclusion will follow. But the most common case in practice is when s is less than e; then no light is wasted and the pupil of the eye is filled. The light received is $\left(\frac{o}{e}\right)^2$ times that the naked eye would receive, and the magnification of the apparent area is $\left(\frac{o}{s}\right)^2$. The brightness of image then is to brightness of object seen by the naked eye as

$$\left(\frac{o}{e}\right)^2 : \left(\frac{o}{s}\right)^2, \text{ or as } s^2 : e^2;$$

that is, as the area of the circle to the area of the pupil of the eye. So that for real or extended surfaces of light under view, it is impossible by any optical arrangement to obtain an image whose brightness shall exceed that of the object itself. But this rule will not hold in regard to the brightness of stars in all particulars. They are really points of light and their images are due to the intensity of the light source as a point. If we call the light which a star sends to the naked eye unity, the light seen in its image will be $\left(\frac{o}{s}\right)^2$, if we neglect reflection and absorption in the path of the ray through the lenses, and it is the square of linear magnification if the false disc equals the pupil of the eye in diameter. But if the power is increased by change of eye-piece the disc will be diminished in size and thereafter the quantity of light remains unchanged being $\left(\frac{o}{e}\right)^2$. This expression is the measure of the space-penetrating power of the telescope, shown in revealing faint stars. Large apertures furnish great advantage in this respect. The visibility of faint stars in the telescope is also promoted by darkening the background of the sky surrounding the star which varies directly as s^2 and inversely as the magnifying power if s is less than e. Hence use high power for faint stars. But in the case of a faint comet or a faint nebula the low power is obviously needed for best results.

23. Is the illumination of the image of a star in the telescope altogether a function of the object-glass? W. B. H.

Answer.—No; see answer to number 22.

24. Capt. Wm. Noble in his book entitled *Hours with the three-inch Telescope*, recommends the use of power 160 in viewing stars like the companion of Polaris. Why not use a lower power? Your querist can not see that star with a 3½-inch glass with power as high as 160. W. B. H.

Answer.—The companion to Polaris should be easy in a three-inch telescope. Dawes proposed it as a general standard finding that a power of 80 on a two-inch glass would show it, if the eye and telescope are good. Other astronomers have

seen it with less aperture. Amateurs must not be discouraged by what the keen-eyed, experienced professionals can do. Knowledge of the star's place and how it looks help much in such tests.

25. Professor Swift says (November number) that the great nebula of Andromeda is spectroscopically a star cluster. The Celestial Handbook by Poole Brothers says that spectrum analysis indicates that this nebula is entirely gaseous.

Answer.—The nebula of Andromeda is classed with the white nebulæ and the spectrum of it is continuous, and according to Young "perfectly expressionless," meaning by that, it is unmarked by any lines or bands, either bright or dark. Although the spectrum looks like that of a stellar cluster, a gaseous mass under pressure would appear in the same way. So also do masses of solid or liquid when heated to incandescence. Neither the spectroscope nor the telescope decide anything conclusively about the white nebulæ especially the brightest one of them all, the Andromeda nebula. While there are observations that support the two views given above, it seems to us that they have not been sufficient to decied the question.

GENERAL NOTES.

It is suggested to subscribers that remittances should be made in advance unless arrangements with the publisher provide for a later pay day.

H. H. Turner Honored.—On the 14th of February a complimentary dinner was given to Professor H. H. Turner, by the staff of Royal Observatory, Greenwich, and other astronomical friends. Professor Turner has recently been appointed to succeed the late Professor Pritchard at Oxford.

The Arago Gold Medal.—On Feb. 6, Professor E. E. Barnard of Lick Observatory, Mt. Hamilton, received the Arago Gold Medal from the Academy of Sciences of France given on account of the discovery of the fifth satellite of Jupiter. A fuller note concerning this medal will be found in the January number of *Astronomy and Astro-Physics*, page 81.

Miss Dorothea Klumpke now at the Bureau of Measurements, Paris Observatory, received the degree of Doctor of Sciences on the 14th of December, 1893. She was formerly from California and is recently spoken of in the French papers as the young American woman. She was given equatorial work in the Paris Observatory under the late Admiral Mouchez, who spoke freely of her aptitude and skill in work requiring patience and precision. The theses which she presented to the Faculty of Sciences of Paris for the doctor's degree in mathematical science are papers worthy of extended notice which will soon be given in *Astronomy and Astro-Physics*. But the amusing thing for western Americans to read from French papers is the suggestion that scholars should not be surprised at the success of young women in mathematics, for physiologists now claim that the female brain is peculiarly adapted to the study of the exact sciences, and that the few cases known, comparatively, are due to custom rather than natural aptitude. What a discovery for a physiologist to make! The western schoolmaster knew that a half century ago.

Errata.—In December number, 1893, p. 148. The Perseid radiant given as 49° + 67° in the table should be 49° + 57°.

February, 1894, p. 272. The correct figures showing the close agreement in independent determinations of the Perseid radiant, should be as follows:—

	1879. Aug. Radiant.		1880. Aug. Radiant.	
	°	°	°	°
G. L. Tupman.....	45	+ 56	44	+ 56
H. Corder.....	45	+ 57	45	+ 58
E. F. Sawyer.....	44½	+ 57	44¾	+ 56¼
W. F. Denning.....	46	+ 58	44	+ 56

February, 1894, page 254, line 7, "west" should be inserted before the first word "point;" line 9, "to" should read "of."

PUBLISHER'S NOTICES.

The attention of subscribers is called to the fact that subscriptions should be paid promptly in advance, unless arrangements have been made with the publisher for a later time of payment.

It will not be possible to send proofs of articles to contributors in consequence of the necessity of doing this in the case of the more technical articles prepared for *Astronomy and Astro-Physics*. The matter for *Popular Astronomy* is expected to be so plainly worded that it ought not to be necessary to furnish authors' proofs, especially if the copy is well prepared. It is often necessary to hold fifty pages in type eight or ten days in order to furnish authors' proofs for the first-named publication. It will readily be seen that such a course could not be pursued in both publications which are issued almost simultaneously.

Patrons will also please remember that all dues to this publication should be sent to Charlotte R. Willard, Goodsell Observatory of Carleton College, Northfield, Minnesota, U. S. A., and that matter for publication may be sent to Miss Willard or to the publisher, William W. Payne, having the same address. All drawings for illustration should be *very carefully* made, in india ink, and double the size intended for the printed page, as such reductions give better results than that from copy of less size.

It has been encouraging to learn from various sources so soon after printing our first map that the star-charts by the Poole Brothers, of Chicago, have created so much interest in the study of the constellations. Under date of February 5th, Professor Winslow Upton, Ladd Observatory of Brown University, Providence, R. I., the author of the series of papers now being published in this magazine, says: "It seems to me the map (meaning the star-chart of the February number) is a decided success, and I see nothing to critcise in it. It pleases me very much, and makes the completion of my articles much more satisfactory to me and I hope to your readers."

This is high commendation, and we are gratified to reproduce such a testimony from one whose accurate and general scholarship is well known to practical astronomy.

Poole Brothers' Celestial Handbook is a delightful companion to the series of star-charts now being published in this magazine. It is a volume of one hundred pages, clearly printed on superior paper and admirably illustrated. The greater part of the book is occupied with a study of the constellations, these being presented in three groups, namely:—Constellations North of the Zodiac, Zodiacal Constellations, and Constellations South of the Zodiac. Under each constellation there is a condensed statement of its history and mythological character, a list of the principal stars, with their magnitudes, right ascensions and declinations; and series of "notes," giving valuable and interesting information, such as magnitudes of the components of a double, number of stars in a given cluster, suggestion of an interesting field for a small glass, parallax of a star, peculiarities of a variable, results of spectroscopic investigation, etc.

Many of the striking features of the constellations are presented in illustrations, there being seventy illustrations of "Double and Triple Stars, Binaries and Trinaries," forty of "Clusters and Nebulæ," and thirty diagrams showing "Orbits of Stars, etc." Following this detailed work is a table of "Old and New Constellations in Chronological Order;" a quotation will show the character of the table: "Ursa Major; Job XXXVIII. (17 Cent. B. C.?), Homer (9th Cent. B. C.)" Other subjects presented in tabular form are: Names Given to the Principal Stars, The Principal Binary Stars, Finest Colored Double Stars, Finest White Double Stars, Stars for Which a Parallax has been Found, Stars of Greatest Proper Motion. A brief chapter is devoted to each of the subjects, Shooting Stars, Comets, Planets. The purpose of the book is clearly stated in these words found at its close: "We desire to say that our Handbook is intended for the general public who wish to obtain a fair idea of the beauty of the heavens without great expense of time or money.

MAP OF THE

CONSTELLATIONS

VISIBLE MARCH 15, AT 9 P. M.

REDUCED FROM SECTION OF POOLE BROTHERS' PLANISPHERE.

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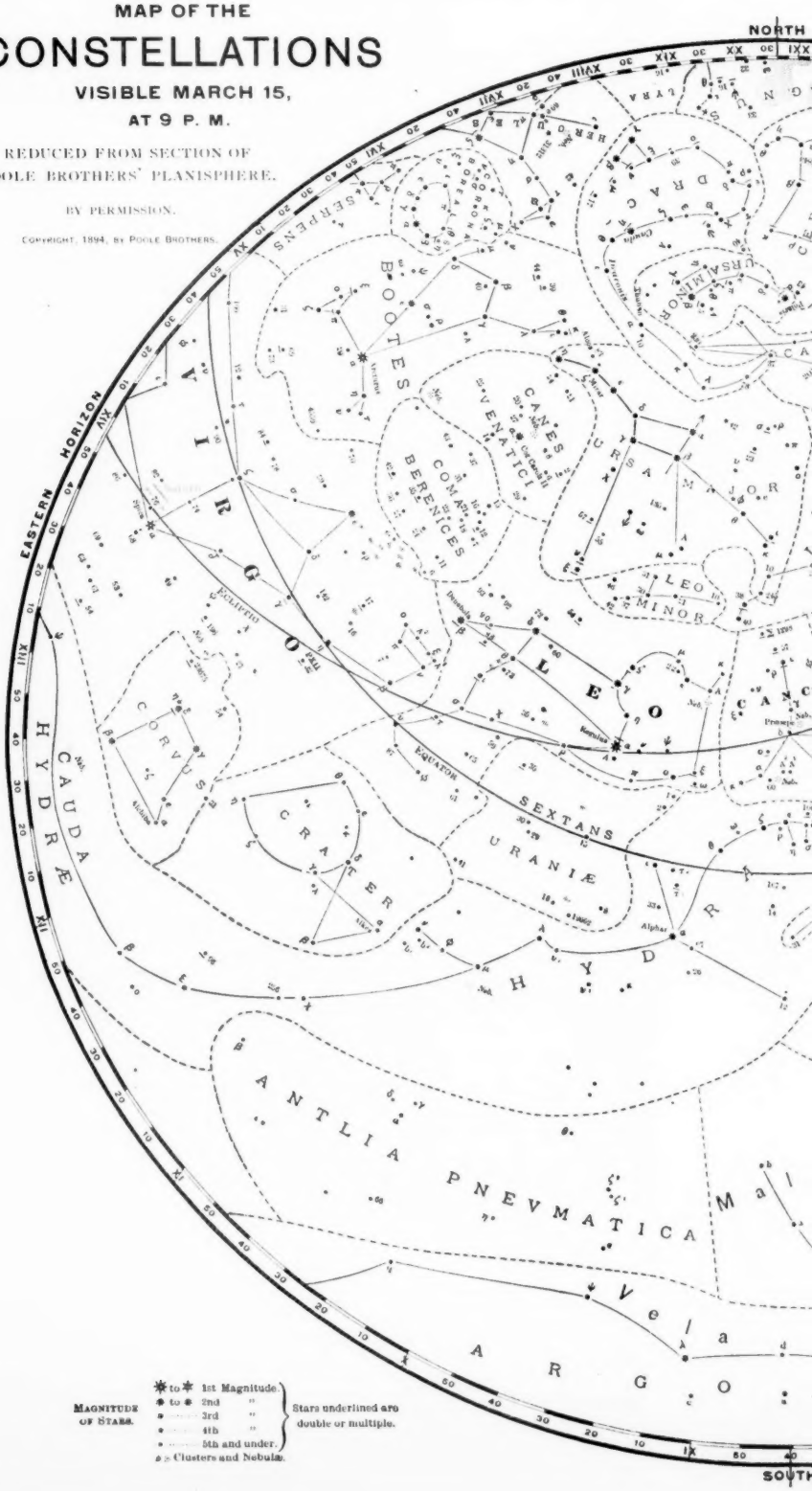
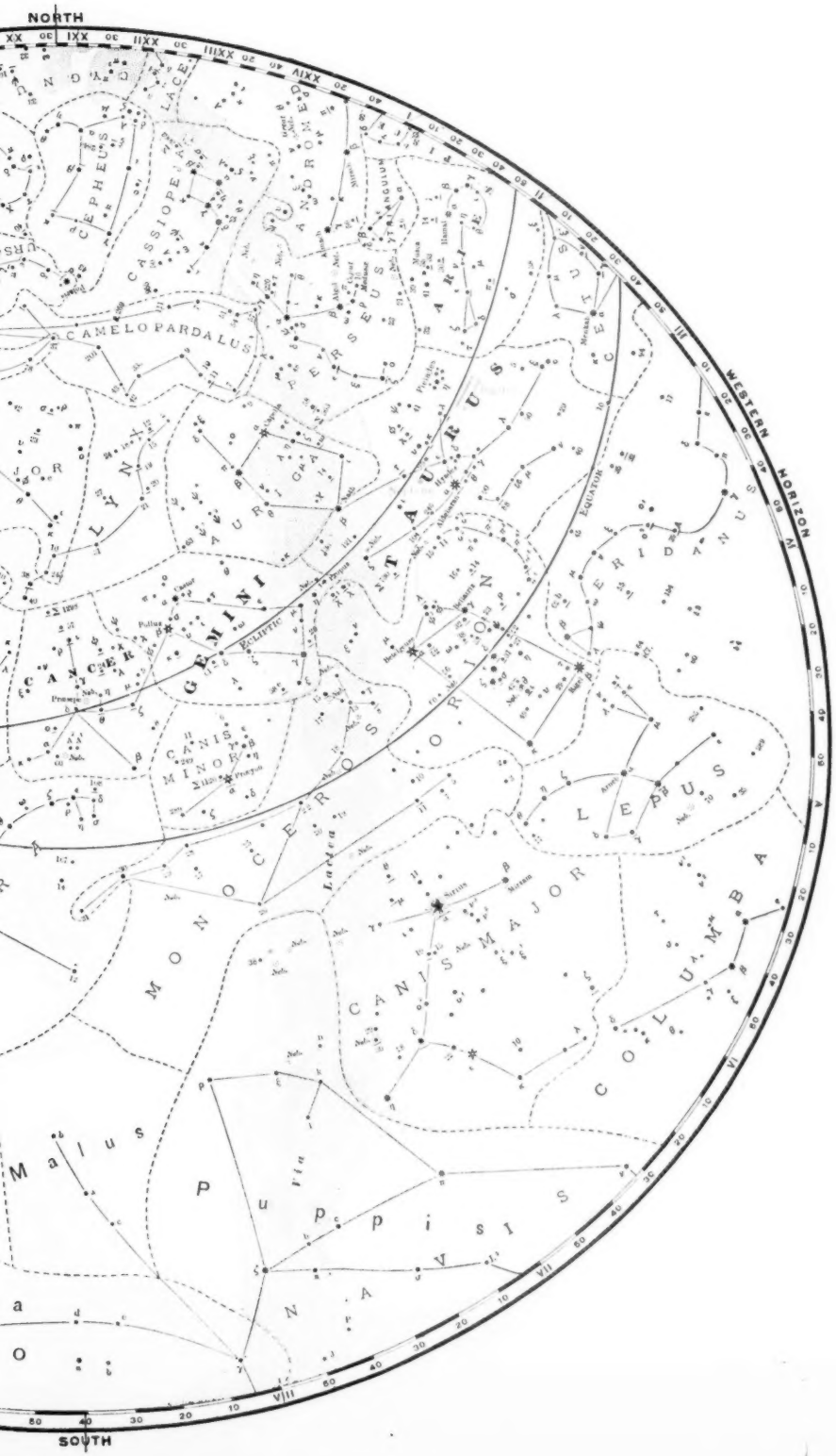


MAGNITUDE OF STARS.

- ✱ to ✱ 1st Magnitude.
- ✱ to ● 2nd "
- ● 3rd "
- ● 4th "
- · 5th and under.

Stars underlined are double or multiple.

⊕ Clusters and Nebulæ.


NORTH
WESTERN HORIZON
SOUTH
CEPHEUS
CASSIOPEIA
CAMELOPARDALUS
PERSEUS
ANDROMEDA
ARIES
TRIANGULUM
TAURUS
AURIGA
LYNX
GEMINI
CANCER
CANIS MINOR
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Menkar
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Alcyone
Menkalinan
Nath
Arneb
Mintaka